KANSAS LOWER REPUBLICAN BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody / Assessment Unit (AU): Crooked Creek and Stranger Creek Watershed
Water Quality Impairment: Total Phosphorus

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Lower Kansas **Counties:** Atchison, Jefferson, and Leavenworth

HUC8: 10270104 **HUC10 (12**): 1027010403 (01, 02, 03, 04, 05, 06, 07)

Ecoregion: Western Corn Belt Plains, Loess and Glacial Drift Hills (47i) and Central Irregular Plains, Osage Cuestas (40b)

Drainage Area: 292.4 Square Miles

Water Quality Limited Segments:

Main Stem	***Tributaries***	
Stranger Cr (7)		
Stranger Cr (8)	Walnut Cr (13)	Prairie Cr (47) Indian Cr (48) Scatter Cr (9013)
	Brush Cr, West (46)	
	Dawson Cr (45)	
	Buttermilk Cr (44)	
Stranger Cr (9)	Crooked Cr (10)	
	Crooked Cr (12)	Unnamed Stream (11) Mooney Cr (1011) Howard Cr (43) Hulls Branch (42)
	Camp Cr (41)	
	Little Stranger Cr (959)	

Designated Uses for Main Stem Stranger Creek (7, 8, 9): Expected Aquatic Life, Drinking Water Supply, Food Procurement, Groundwater Recharge, Industrial Water Use, Irrigation Use, and Livestock Watering Use. Contact Recreation use varies as follows: Primary Contact Recreation Class C; Secondary Contact Recreation Class b. Designated uses for tributaries in the Stranger Creek watershed are detailed in **Table 1.**

Table 1. Designated Uses for Tributaries in the Crooked Creek and Stranger Creek Watersheds.

Tributary	Segment #	Expected Aquatic Life	Contact Recreation	Drinking Supply	Food Procurement	Ground Water Recharge	Industrial Water Use	Irrigation Use	Livestock Watering Use
Walnut Cr	13	Y	b	Y	Y	Y	Y	Y	Y
Prairie Cr	47	Y	b	Y	Y	Y	Y	Y	Y
Indian Cr	48	Y	b	N	N	N	N	Y	Y
Scatter Cr	9013	Y	b	N	Y	N	N	Y	Y
Brush Cr, West	46	Y	b	N	N	N	N	Y	Y
Dawson Cr	45	Y	b	Y	N	Y	Y	Y	Y
Buttermilk Cr	44	Y	b	N	N	Y	N	Y	Y
Crooked Cr	10	Y	C	Y	Y	Y	Y	Y	Y
Crooked Cr	12	Y	C	Y	Y	Y	Y	Y	Y
Unnamed Stream	11	Y	b	N	N	N	N	Y	Y
Mooney Cr	1011	Y	b	Y	Y	Y	Y	Y	Y
Howard Cr	43	Y	b	N	Y	Y	N	N	Y
Hulls Branch	42	Y	b	N	Y	N	N	N	N
Camp Cr	41	Y	b	Y	N	Y	Y	Y	Y
Little Stranger Cr	959	Y	C	Y	Y	Y	Y	Y	Y

Y = Yes (use is designated); N = No (use is not designated)

303(d) Listings:

Station SC683, Crooked Creek near Winchester Total Phosphorus (TP) Impairment: 2008, 2010, 2012 and 2016 Kansas/ Lower Republican River Basin Streams (**Figure 1**).

Station SC602, Stranger Creek near Easton, Total Phosphorus (TP) Impairment: 2008, 2010, 2012 and 2016 Kansas/ Lower Republican River Basin Streams (**Figure 1**).

Impaired Use: Aquatic Life, Contact Recreation, and Domestic Water Supply.

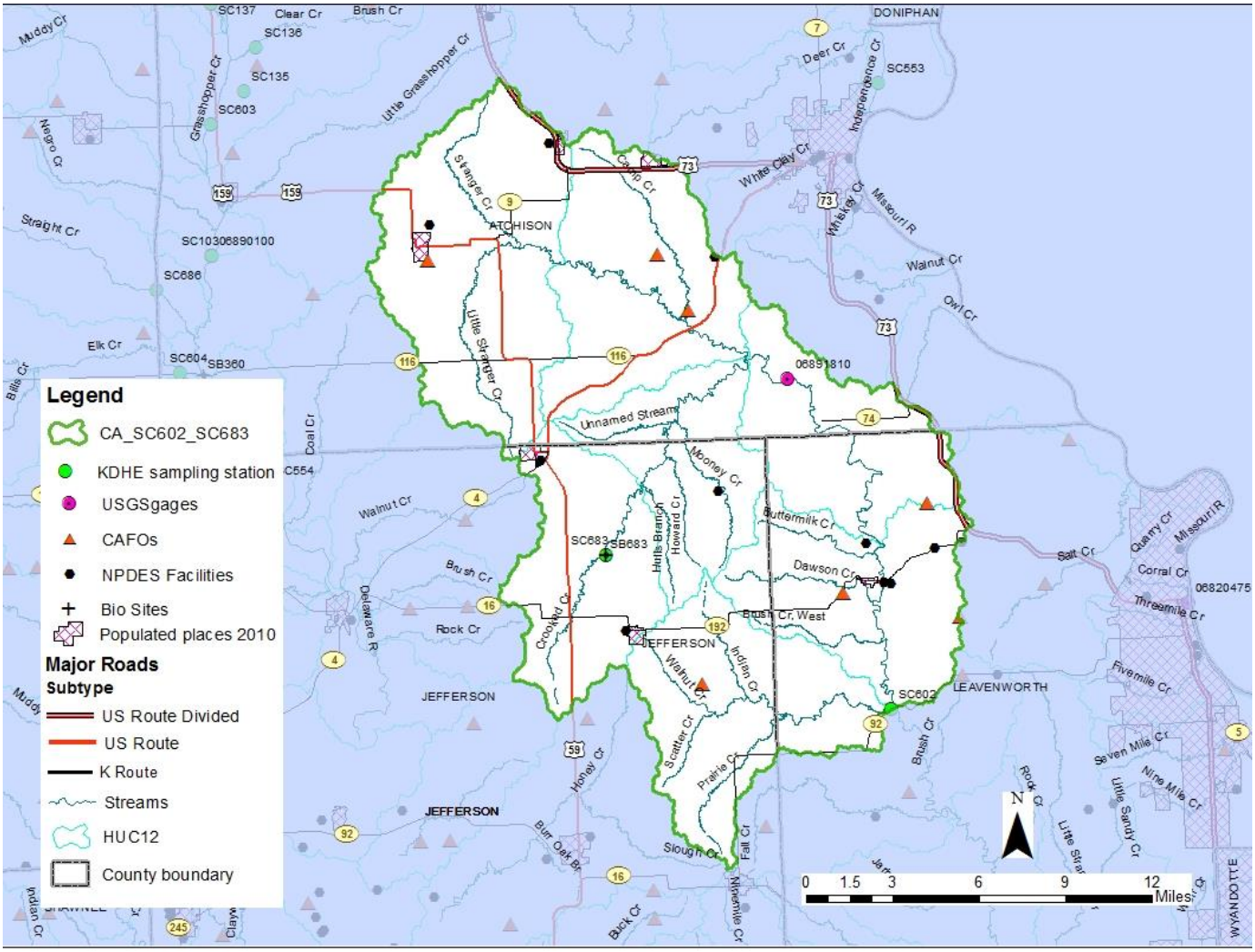

Figure 1. Crooked Creek and Stranger Creek Watersheds.

Water Quality Criteria:

Nutrients – Narratives: Taste-producing and odor-producing substances of artificial origin shall not occur in surface waters at concentrations that interfere with the production of potable water by conventional water treatment processes, that impart an unpalatable flavor to edible aquatic or semiaquatic life or terrestrial wildlife, or that result in noticeable odors in the vicinity of surface waters (KAR 28-16-28e(b)(7)).

The introduction of plant nutrients into surface waters designated for domestic water supply use shall be controlled to prevent interference with the production of drinking water (K.A.R. 28-16-28e(d)(3)(D)).

The introduction of plant nutrients into streams, lakes, or wetlands from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the projection of undesirable quantities or kinds of aquatic life (K.A.R. 28-16-28e(d)(2)(A)).

The introduction of plant nutrients into surface waters designated for primary or secondary contact recreational use shall be controlled to prevent the development of objectionable concentrations of algae

or algal by-products or nuisance growths of submersed, floating, or emergent aquatic vegetation (K.A.R. 28-16-28e(d)(7)(A)).

The concentration of dissolved oxygen in surface waters shall not be lowered by the influence of artificial sources of pollution. The Dissolved Oxygen criterion is 5.0 milligrams per liter (K.A.R. 28-16-28e(e), Table 1g).

2.0 CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Uses under the 2016 303(d) List: Phosphorus levels in Crooked Creek near Winchester (SC683) and Stranger Creek near Easton (SC602) are consistently high. Excessive nutrients are not being controlled and are thus impairing aquatic life, domestic water supply, and contact recreation.

Stream Chemistry Monitoring Sites and Periods of Record:
Active KDHE Rotational ambient Stream Chemistry sampling station SC683, located on Crooked Creek ¼ mile west, 2 ½ miles north, and ¾ mile west of Winchester.
Period of Record: Sampled bimonthly in 1995, 1999, 2003, 2007 and quarterly in 2011 and 2015.

Active KDHE Rotational ambient Stream Chemistry sampling station SC602, located on Stanger Creek 4¾ mile and ½ mile east of Easton.
Period of Record: Sampled bimonthly in 1991, 1995, 1999, 2003, 2007 and quarterly in 2011 and 2015.

Stream Biology Monitoring Sites and Periods of Record:
Station SB683: Crooked Creek at County road ¼ mile west, 2 ½ miles north, and ¾ mile west of Winchester.
Period of Record: 1992- 2014. Two samples were taken in 1992 and 1993 and one sample was taken from 1994-2014 except 1995, 2008, 2010, 2011, and 2012 where there was no data collected.

Flow Record: USGS Gage 06891810 on Stranger Creek near Potter (Period of Record:10/1/2003-6/9/2015) and USGS Gage 06892000 on Stranger Creek near Tonganoxie (Period of Record: 1/1/1990-12/31/2016) and were utilized to establish flow conditions in the watershed.

Flow Conditions: Flow conditions were established based on USGS gage 06891810, with adjustments being made based on the watershed size at the sampling station. The flow record for the sampling years when the USGS gage 06891810 was not active (01/1991-10/2003 and 07/2015-10/2015) is based on estimates from the USGS Gage 06892000. Long term flow conditions as calculated from USGS flow data for the period of record from 06891810 (1991-2015) and USGS Gages 06892000 (1990-2016) on Stranger Creek is shown in **Table 2.** The flow duration curve covering the period of record from 1990-2016 are illustrated for Crooked Creek and Stranger Creek at KDHE sampling stations SC683 and SC602, respectively, in **Figure 2**. **Table 3** displays the USGS estimates of flow duration, mean flow, 2-year peak discharge value for the main stem and tributary segments in the watershed (Perry et al., 2004).

Table 2. Long Term Flow conditions as calculated from USGS flow data for Crooked Creek and Stranger Creek.

Stream Location	Drainage Area (mi2)	Mean Flow (cfs)	Percent of Flow Exceedance (cfs)				
			90%	75%	50%	25%	10%
Stranger Cr near Potter at USGS Gage 06891810	184	240.78	2	6.4	21	49	142
Crooked Cr at SC683	35.5	46.39	0.39	1.22	4.05	9.45	27.49
Crooked Cr at terminus	39.7	28.6	0	0	2.51	10.9	35.8
Stranger Cr at SC602	292.4	381.62	3.18	10.01	33.37	77.87	225.66
Stranger Cr near Tonganoxie at USGS Gage 06892000	406	539.67	4.6	15	49	141	475.3

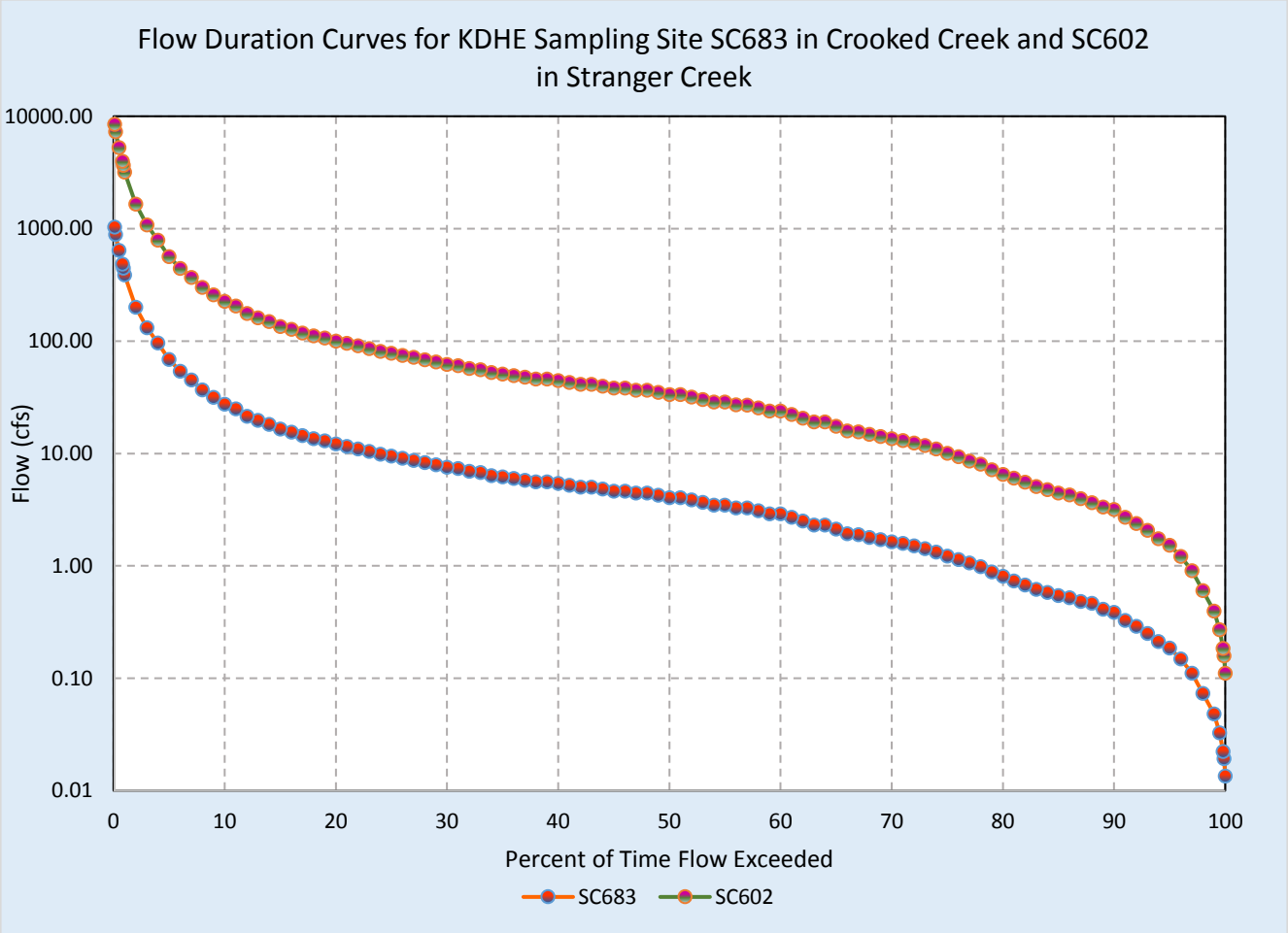

Figure 2. Flow duration on Crooked Creek and Stranger Creek based on watershed ratio calculations from USGS Gage 06891810 and USGS Gage 06892000.

Table 3. Long term estimated flows for Crooked Creek and Stranger Creek and their tributaries in Atchison (AT), Jefferson (JF), and Leavenworth (LV) Counties (Perry et al., 2004).

Stream	USGS Site ID	County	Drainage Area (mi^2)	Flow (cfs)						
				Mean	90%	75%	50%	25%	10%	2-year Peak
Walnut Cr	1411	JF LV	38.7	35.1	0	0.67	5.10	18	51.2	4,830
Prairie Cr	1515	JF	9.68	9.60	0	0	0.97	4.05	12.4	1,410
Indian Cr	1275	JF	1.12	0.25	0	0	0	0	0	390
Indian Cr	1385	JF	7.99	8.19	0	0	1.28	4.14	11.3	1,230
Scatter Cr	1451	JF	10.2	10.2	0	0	1.34	4.81	13.8	1,450
Brush Cr, West	1336	JF LV	9.27	10.1	0	0.13	1.91	5.78	14.9	1,370
Dawson Cr	1281	JF LV	8.28	8.89	0	0	1.45	4.70	12.6	1,260
Buttermilk Cr	1223	JF LV	8.52	8.31	0	0	1.08	3.82	11	1,260
Crooked Cr (10)	1111	AT	75.3	51.3	0.01	0.57	5.36	21.3	68.8	5,050
Crooked Cr (10)	1114	AT	57.3	39.4	0.01	0.14	3.74	15.5	50.9	4,880
Crooked Cr (12)	1145	AT JF	39.7	28.6	0	0	2.51	10.9	35.8	3,970
Crooked Cr (12)	1169	JF	34.7	25.2	0	0	2.10	9.33	31.1	3,850
Crooked Cr (12)	1361	JF	25	18.6	0	0	1.34	6.45	22.1	2,310
Unnamed Stream	1121	AT	17.5	39.4	0	0	1.14	5.02	16.3	1,770
Mooney Cr	1227	AT JF	10.1	8.46	0	0	0.61	2.98	10	1,350
Howard Cr	1224	JF	4.18	3.24	0	0	0	0.38	2.83	812
Hulls Branch	1269	JF	8.33	6.73	0	0	0.21	1.82	7.21	1,230
Camp Cr	993	AT	24.8	19.1	0	0.33	2.96	9.58	26.4	2,110
Little Stranger Cr	1104	AT	30.6	20.07	0	0	1.89	7.93	25.6	2,940

Average annual flow for the KDHE stream sampling sites on Crooked Creek and Stranger Creek was highest in 1999 and lowest in 2003 (SC683) and 1991 (SC602) (**Figure 3 and 4**). Monthly flows (**Figure 5 and 6**) reflect seasonal patterns with higher flows in April and July. The large variation between average and median flows in April can be an indication of short duration high flow events. Seasonal average flows in Crooked Creek and Stranger Creek for sampling sites SC683 and SC602, respectively, are shown in **Table 4.** Average spring (April-June) flow is about two and half times the flow seen during the summer/fall (July-October) season. Summer/fall flows are double that of winter (November- March) season.

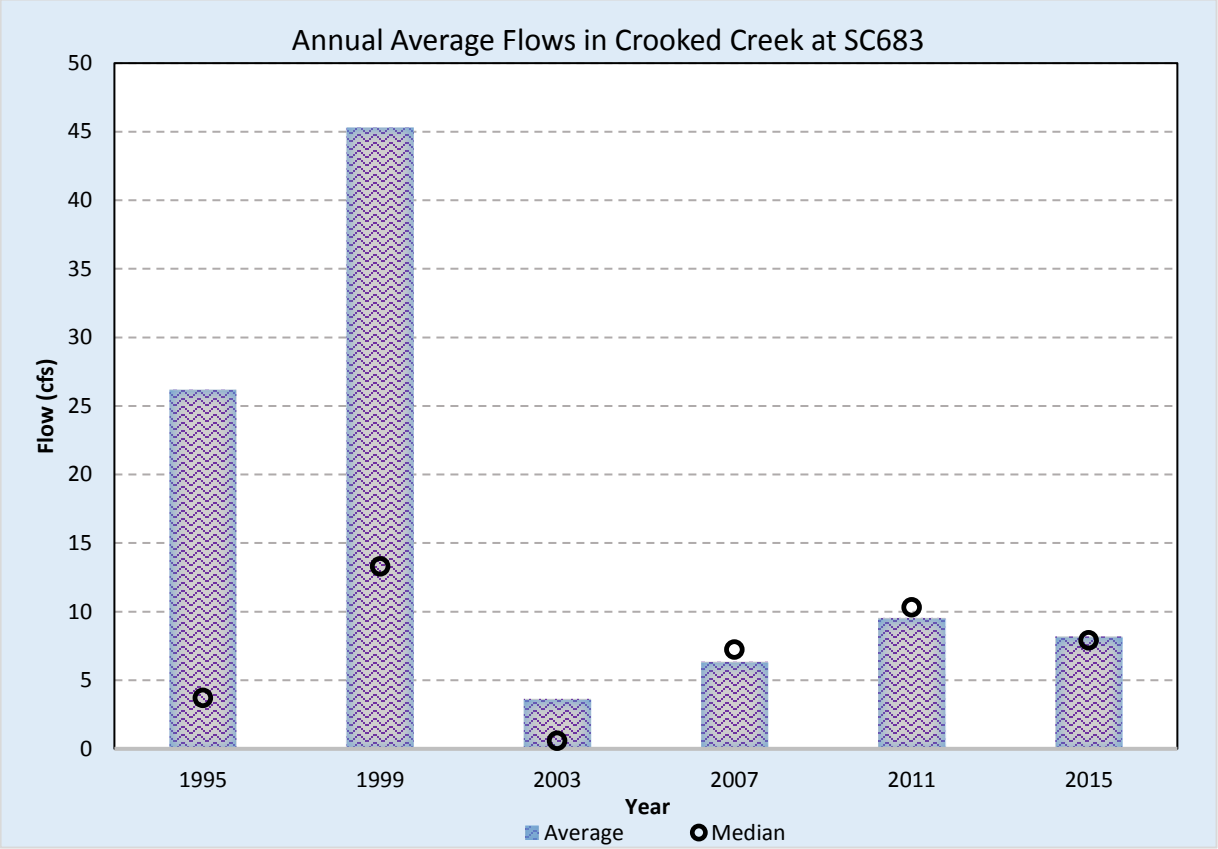

Figure 3. Annual average and median flows at KDHE sampling station SC683 in Crooked Creek.

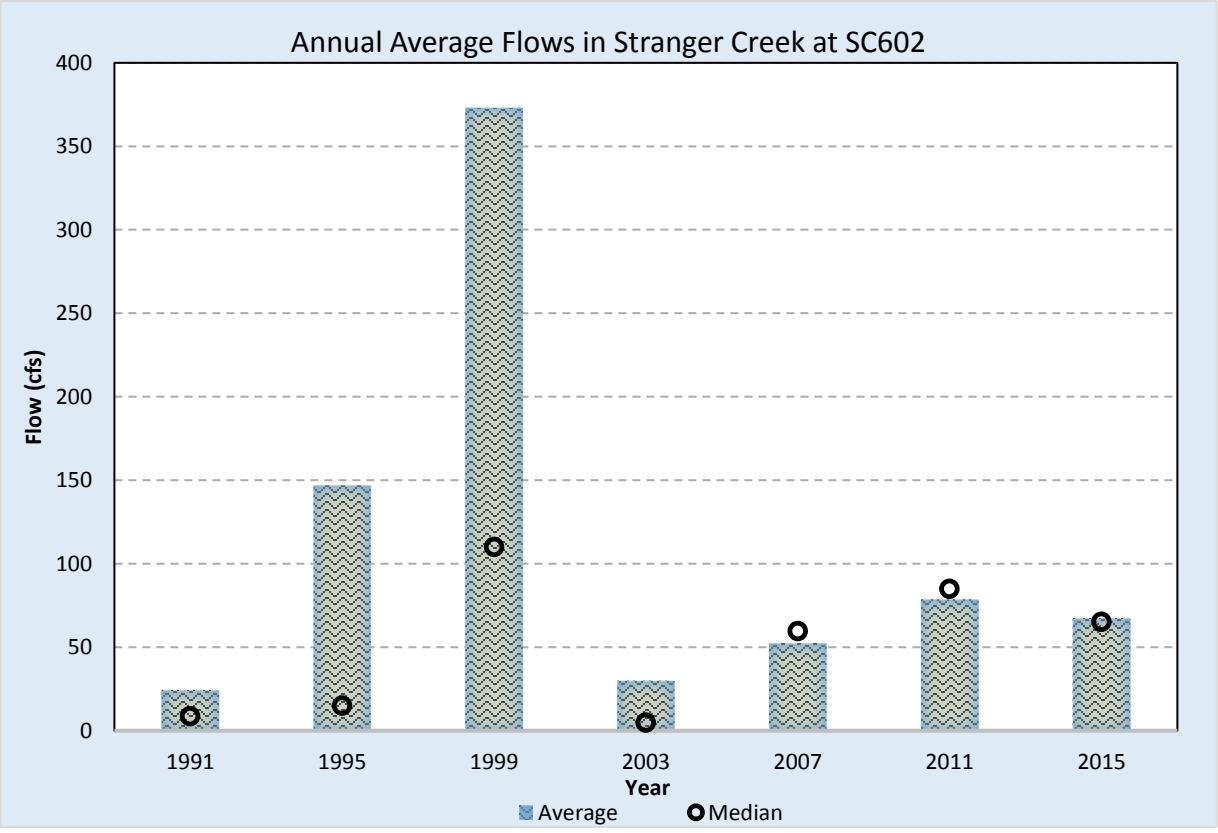

Figure 4. Annual average and median flows at KDHE sampling station SC602 in Stranger Creek.

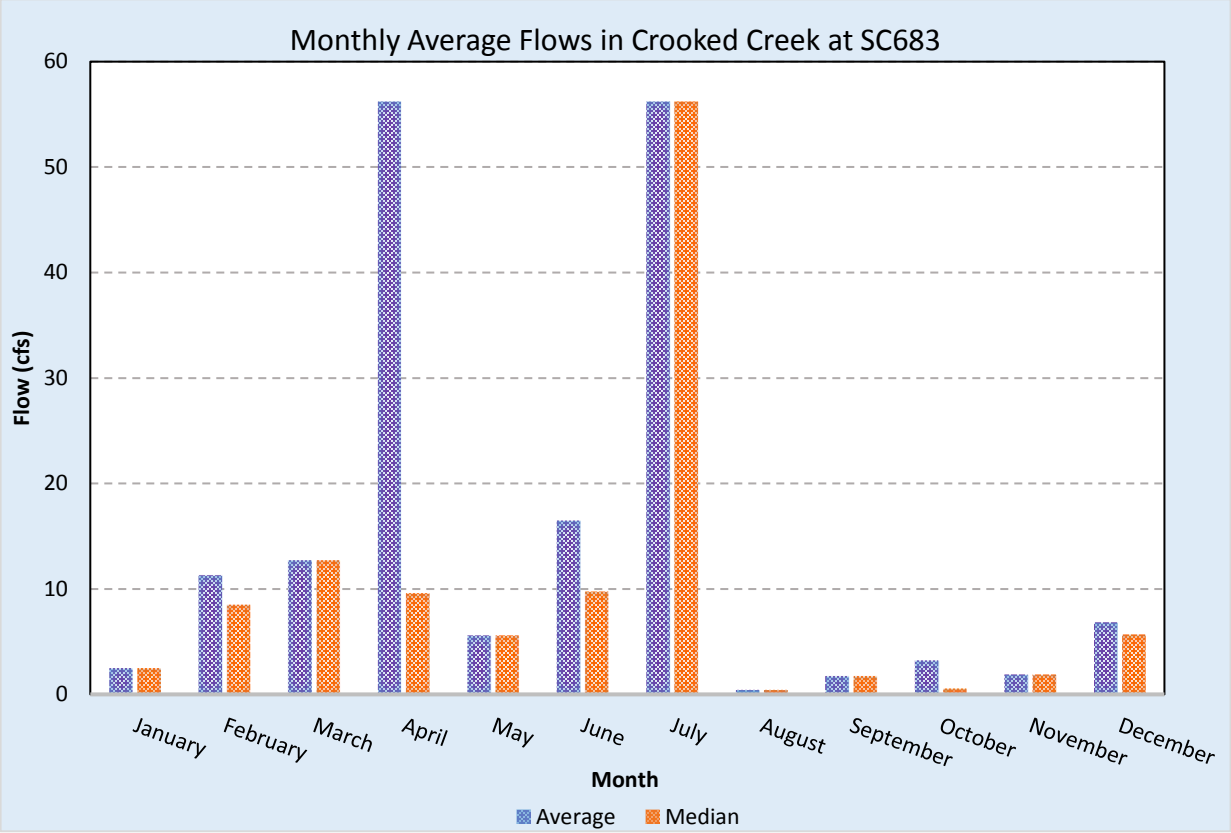

Figure 5. Monthly average and median flows at KDHE sampling station SC683 in Crooked Creek.

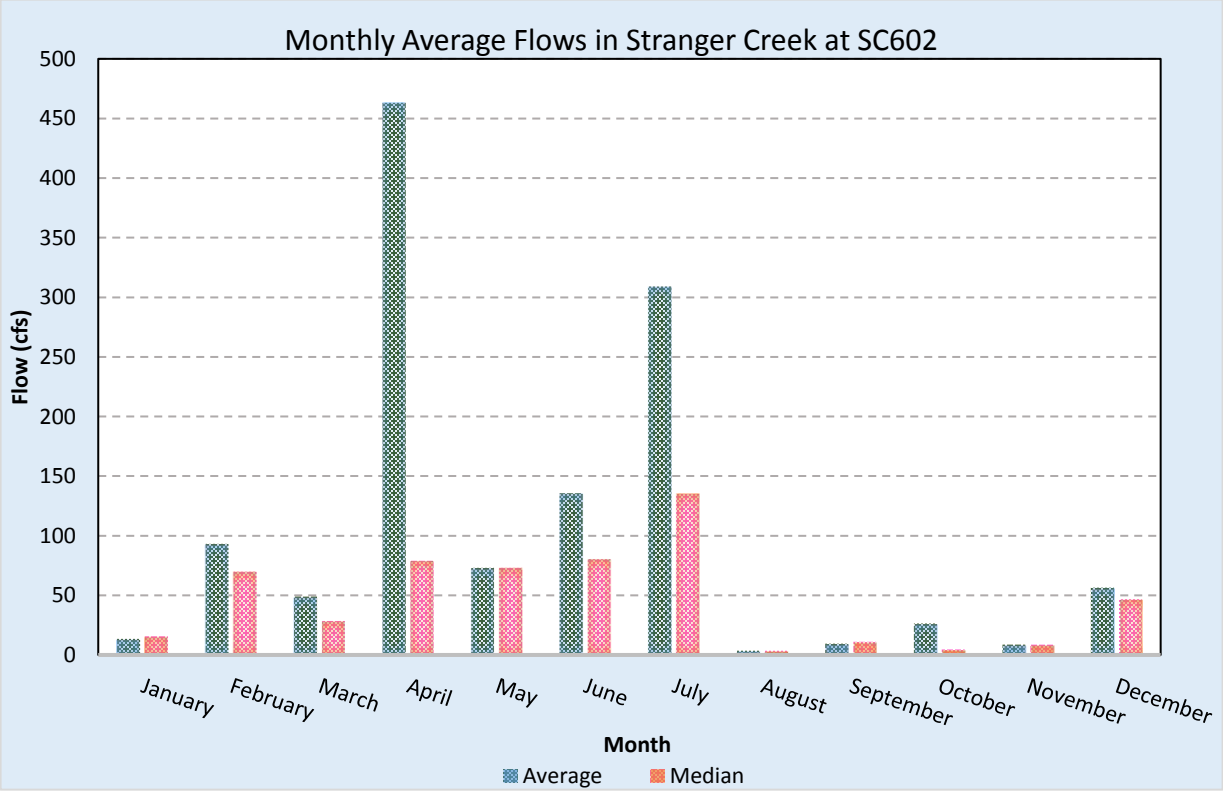

Figure 6. Monthly average and median flows at KDHE sampling station SC602 in Stranger Creek.

Table 4. Seasonal average flows at KDHE sampling sites SC683 in Crooked Creek and SC602 in Stranger Creek.

Sampling Station	Season	Avg Flow (cfs)	Median Flow (cfs)
SC683	Spring	32.90	7.90
	Summer/Fall	12.96	0.96
	Winter	7.84	5.50
SC602	Spring	254	80
	Summer/Fall	89.10	4.60
	Winter	47.30	15.60

Phosphorus Concentrations:
The total phosphorus (TP) concentration average is 0.24 mg/L at SC683 and 0.33 mg/L at SC602. Median concentrations of 0.23 mg/L and 0.25 mg/L for the period of record are seen at SC683 and SC602, respectively. Seasonal TP averages range from a low of 0.26 mg/L in the winter season to a high of 0.57 mg/L in the summer/fall season at SC683. Seasonal TP averages at SC602 are 0.19 mg/L in the winter and 0.45 mg/L in the spring season.

Total phosphorus concentrations by sampling date are graphically represented in **Figures 7 and 8** for SC683 and SC602, respectively. A TP value of 0.72 mg/ L and 1.5 mg/L is observed in a high flow year of 1995 at station SC683 and SC602, respectively.

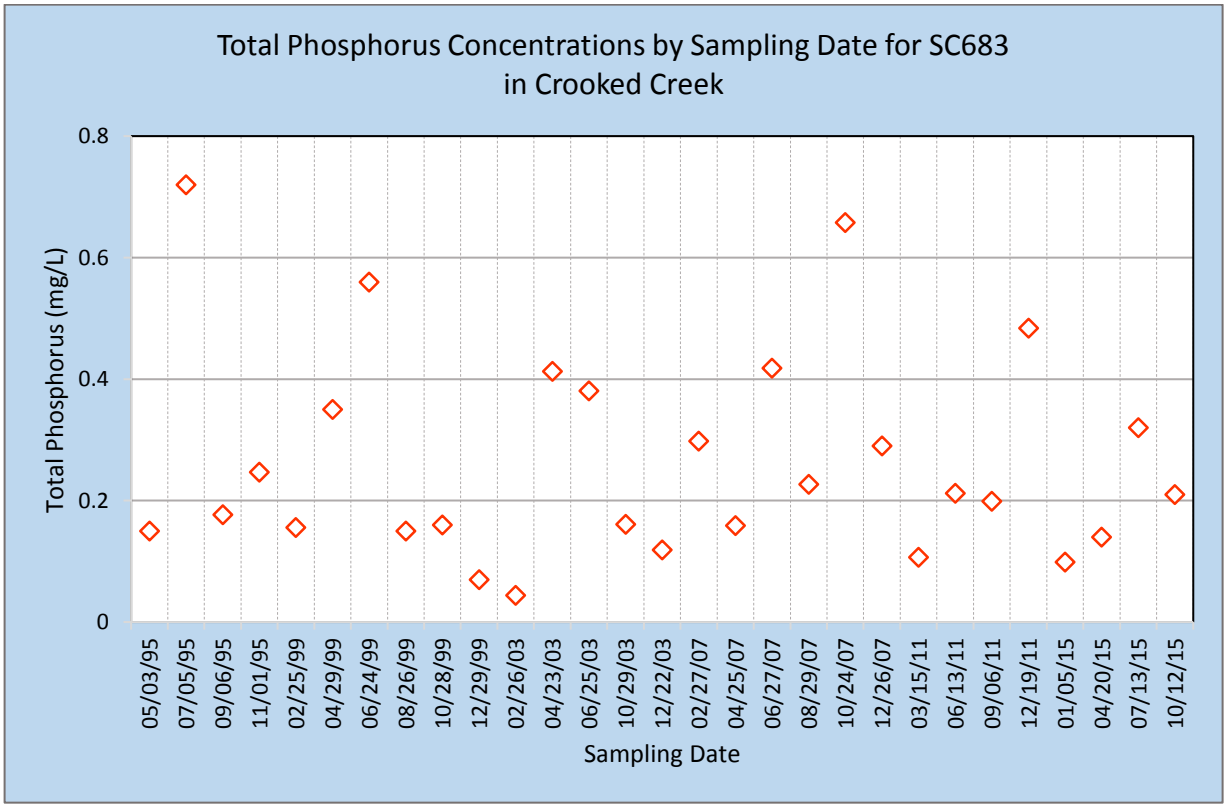

Figure 7. Total phosphorus concentration by sampling date for KDHE sampling site SC683 in Crooked Creek.

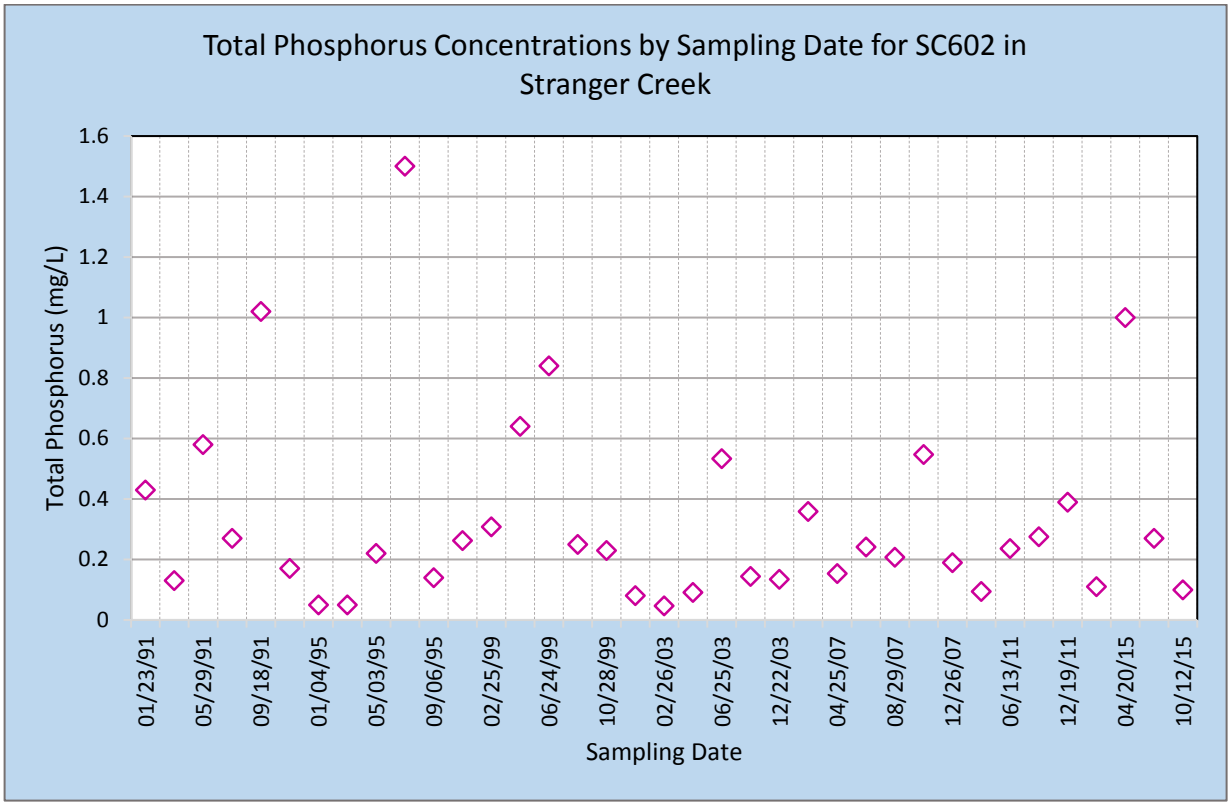

Figure 8.Total phosphorus concentration by sampling date for KDHE sampling site SC602 in Stranger Creek.

The average TP by month in Crooked Creek and Stranger Creek, over the period of record for SC683 and SC602, respectively, are shown in **Figures 9 and 10**. The summer/fall months seem to have an increase in the concentrations of total phosphorus with the highest increase in July. The average annual TP concentrations and the average annual flow at KDHE sampling station SC683 in Crooked Creek and SC602 in Stranger Creek are shown in **Figures 11 and 12**. The highest annual TP concentrations of 0.34 mg/L at SC683 and 0.43 mg/L at SC602 occurred in 2007 and 1991, respectively. A concentration of 0.19 mg/L at SC683 was observed in a low flow year of 2015. Likewise at SC602, a low flow year of 2003, had a TP concentration 0.19 mg/L demonstrating there is no significant effect of nonpoint source on water quality driven by precipitation events.

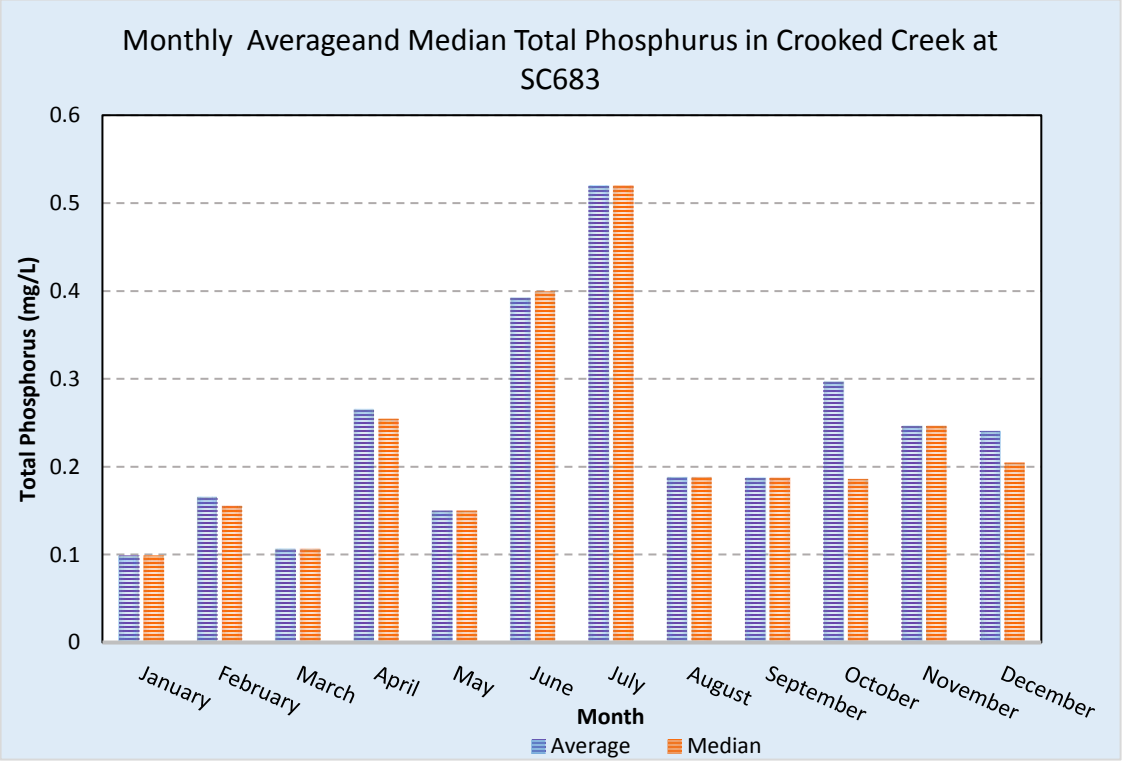

Figure 9. Monthly average and median total phosphorus for KDHE sampling site SC683 in Crooked Creek.

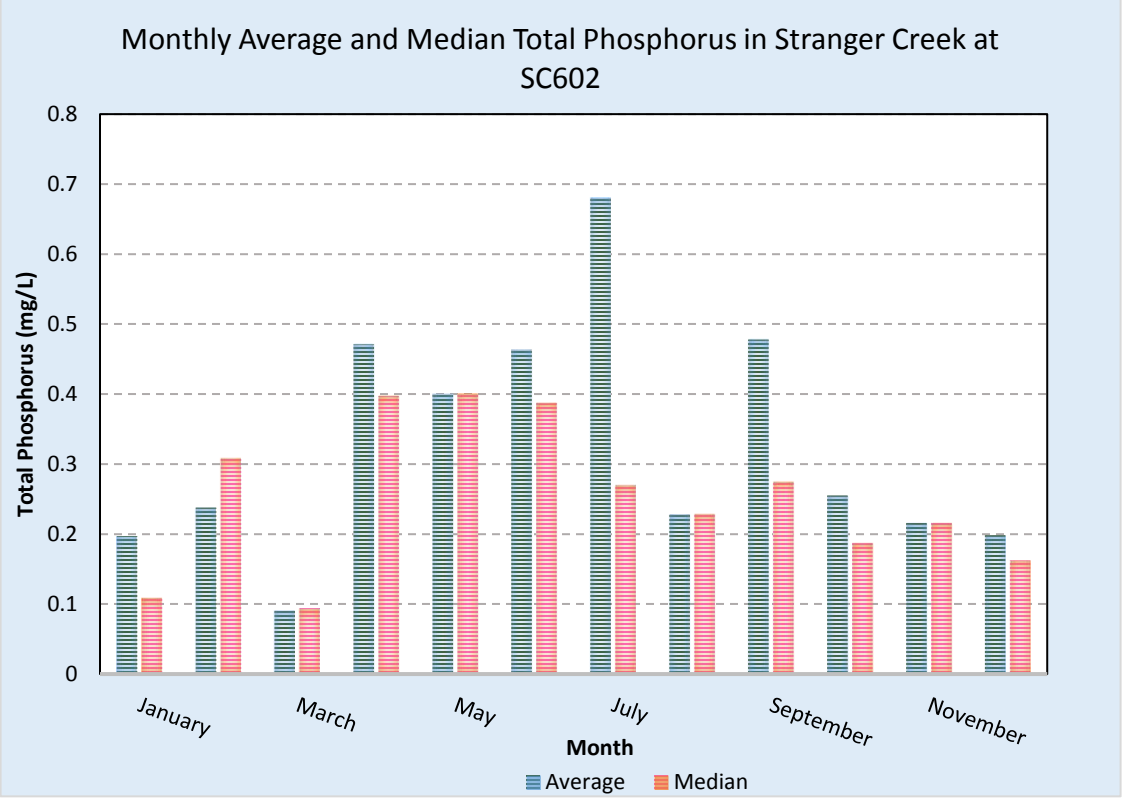

Figure 10. Monthly average and median total phosphorus for KDHE sampling site SC602 in Stranger Creek.

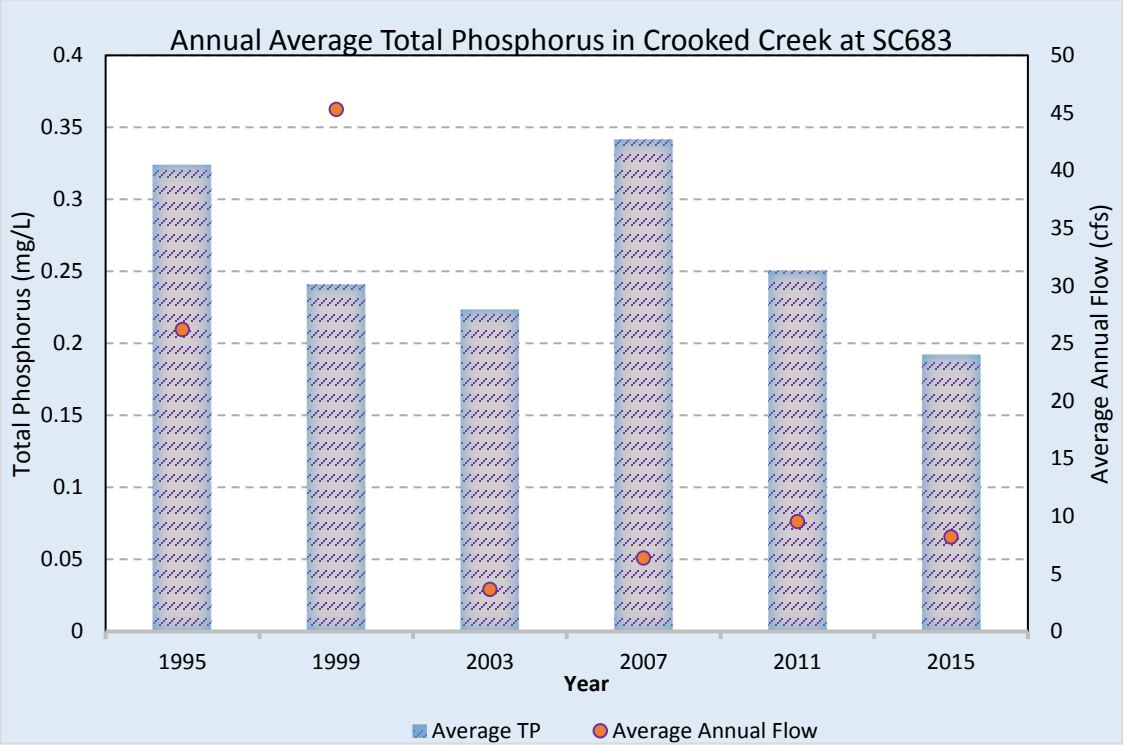

Figure 11. Annual average and median total phosphorus for KDHE sampling site SC683 in Crooked Creek.

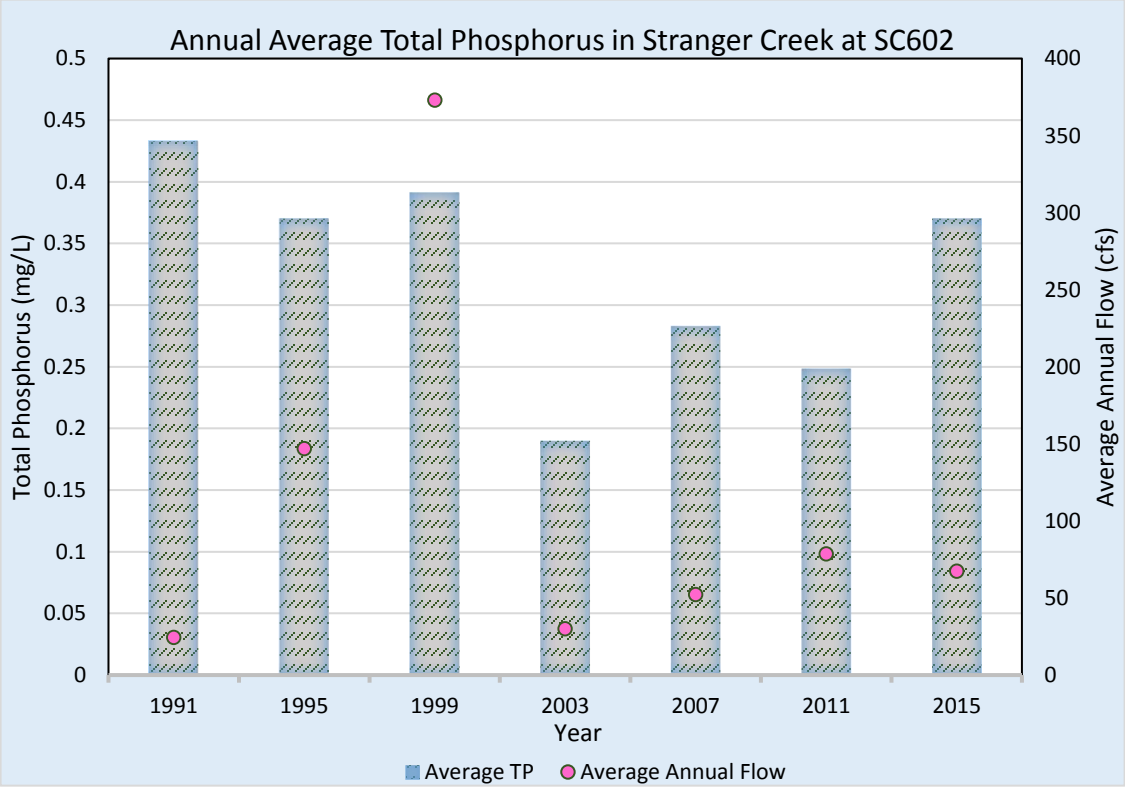

Figure 12. Annual average and median total phosphorus for KDHE sampling site SC602 in Stranger Creek.

Assessment Season: Seasonal variability has been accounted for in this TMDL. A three-season approach was utilized to include: the Spring season consisting of the months of April, May, and June; the Summer-Fall (S/F) season consisting of the months of July, August, September, and October; and the Winter season that includes January, February, March, November, and December.

Seasonal TP averages at SC683 have a low of 0.19 mg/L in the winter season, and measures 0.30 mg/L and 0.31 mg/L in the S/F and spring season, respectively. Seasonal median TP concentrations at SC683 are lowest in the winter at 0.14 mg/L and highest in the spring at 0.35 mg/L. For SC602, seasonal TP averages have a low of 0.19 mg/L in the winter season, and measures 0.41 mg/L in S/F season, with the highest concentration of 0.45 mg/L in the spring season. Seasonal median TP concentrations at SC602 in the winter is lowest at 0.14 mg/L and highest in the spring season at 0.39 mg/L. Seasonal TP concentrations are further detailed in **Figures 13 and 14**. The low TP concentrations occurring during the winter season shows no impact by point sources. However, the higher TP concentrations during spring season indicates the influence of non-point source loading during periods of increased flow due to runoff from high intensity rainfall. The monthly TP values and the monthly median flow values follow a similar trend indicative of non-point source loading in the watershed where months with greater flow register higher TP concentrations.

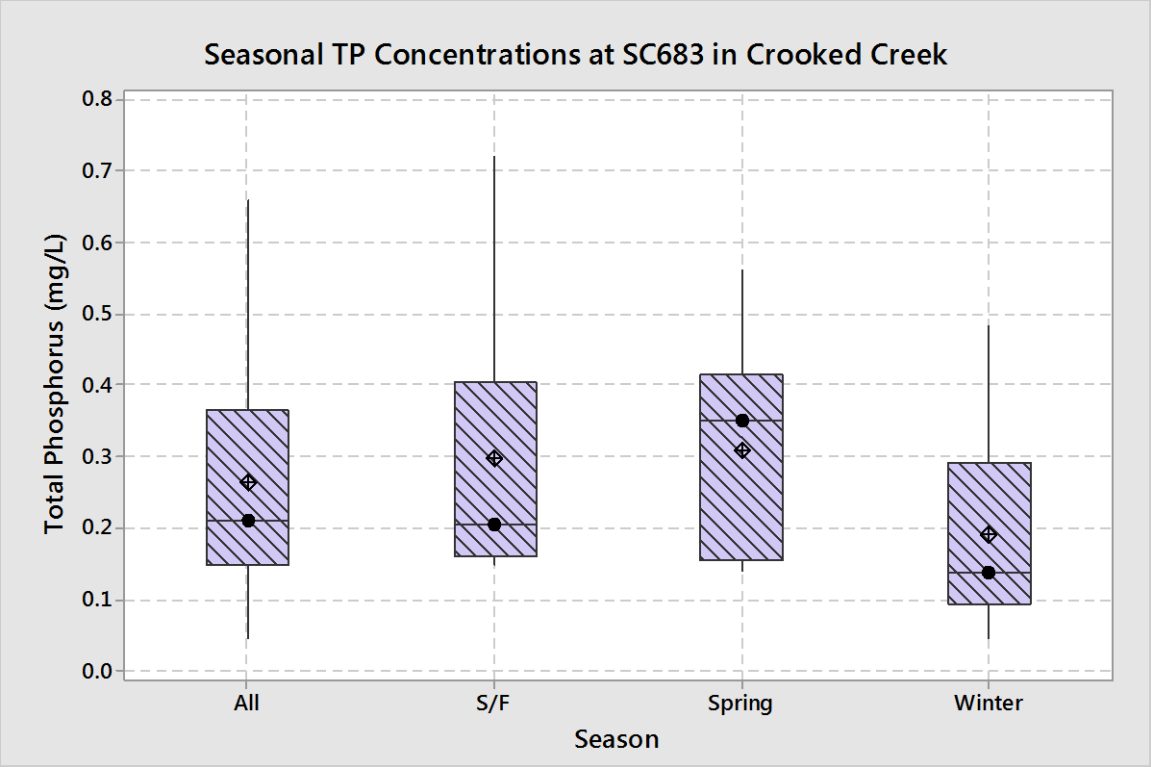

Figure 13. Seasonal total phosphorus at KDHE Sampling site SC683 in Crooked Creek.

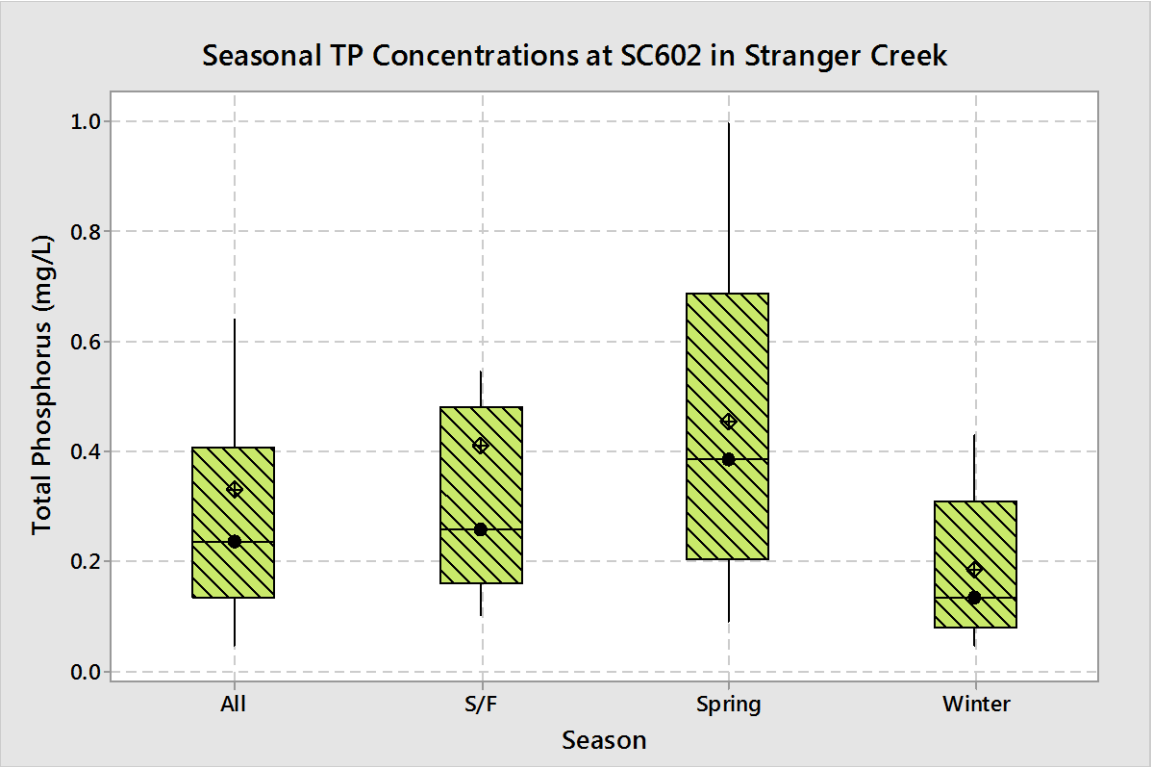

Figure 14. Seasonal total phosphorus at KDHE Sampling site SC602 in Stranger Creek.

Total phosphorus concentration versus the percent flow exceedance in the stream on the day the sample was taken for the KDHE stream-sampling sites (SC638 and SC602) are shown in **Figures 15 and 16.** Phosphorus concentrations increase with increasing flow. The spring season with high to moderate flows shows higher concentrations of TP. Similarly, some of the high flows in S/F also yield high concentrations of TP. This indicates loading is occurring during precipitation events when it is likely that runoff from grazing lands and fertilized cropland in the watershed is reaching the creeks.

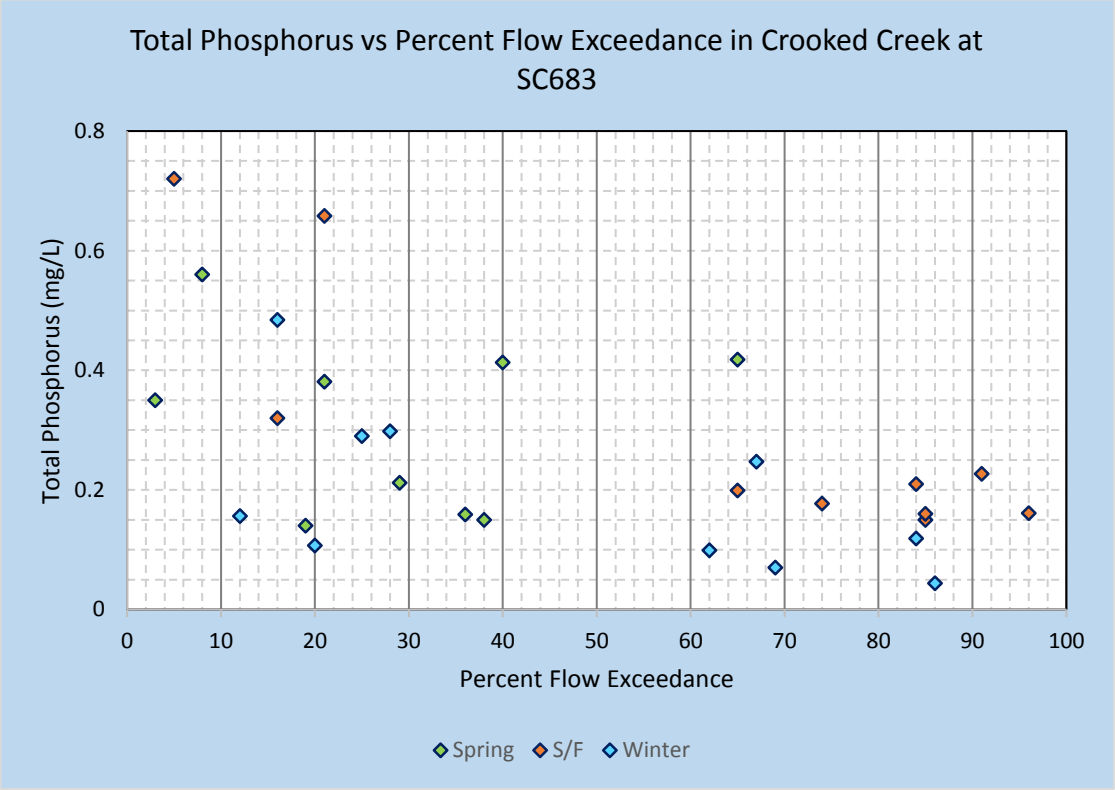

Figure 15. Total phosphorus concentration versus percent flow exceedance at SC683 on the day of sampling.

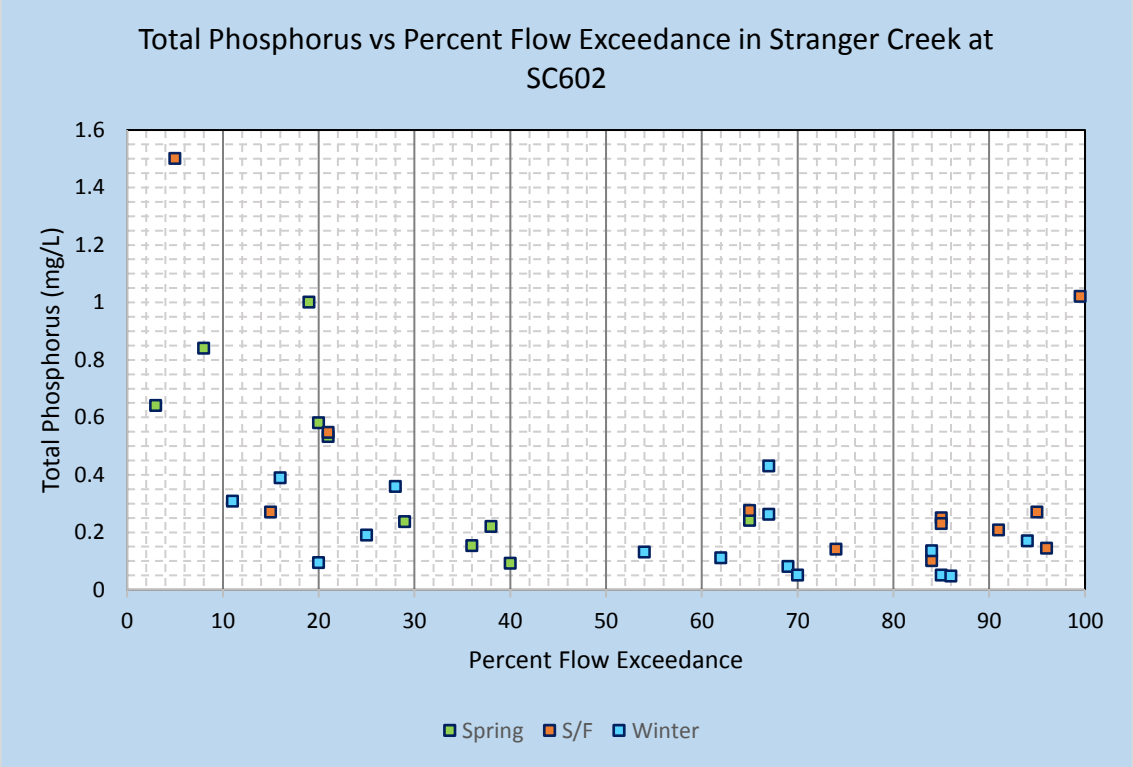

Figure 16. Total phosphorus concentration versus percent flow exceedance at SC602 on the day of sampling.

TP concentrations relative to the flow conditions were assessed and are detailed in **Figures 17 and 18**. High flow samples were obtained when flow was 0-25% flow exceedance; normal flow samples occurred when the stream was between 26-75% flow exceedance; and low flow samples included those taken when the stream was at 76-100% flow exceedance. Phosphorus concentration averages based on the three defined flow conditions are the highest during the high flow condition (0-25% flow exceedance) with an average of 0.38 mg/L and 0.57 for SC683 and SC602, respectively. During normal flows (26-75% flow exceedance) TP averages 0.22 mg/L (SC683) and 0.20 mg/L (SC602). During the low flow condition (76-100% flow exceedance) TP averages 0.15 mg/L (SC683) and 0.24 mg/L (SC602). Median TP concentrations for the normal and low flow conditions are 0.19 mg/L and 0.16 mg/L, and 0.19 mg/L and 0.17 for SC683 and SC602, respectively. Median concentrations are the highest at 0.35 mg/L and 0.54 mg/L for SC683 and SC602, respectively, during the high flow condition.

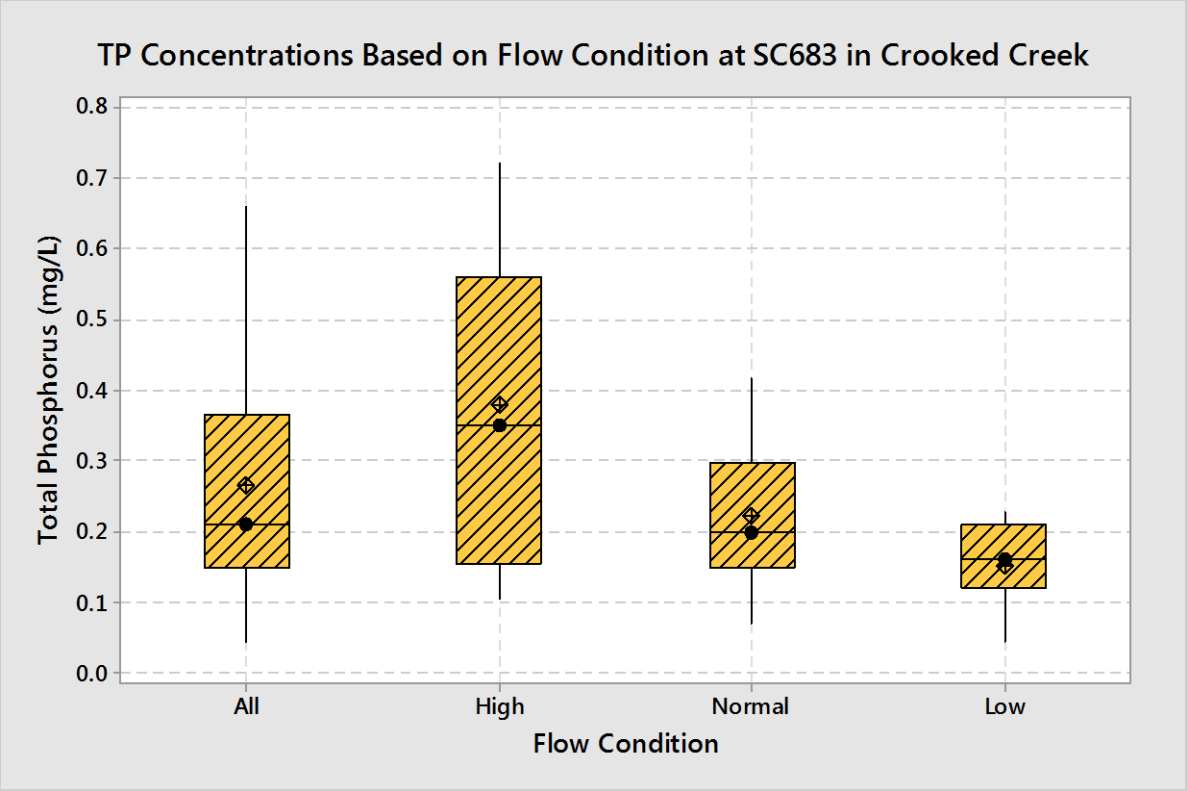

Figure 17. TP concentrations relative to flow condition at KDHE Sampling site SC683 in Crooked Creek

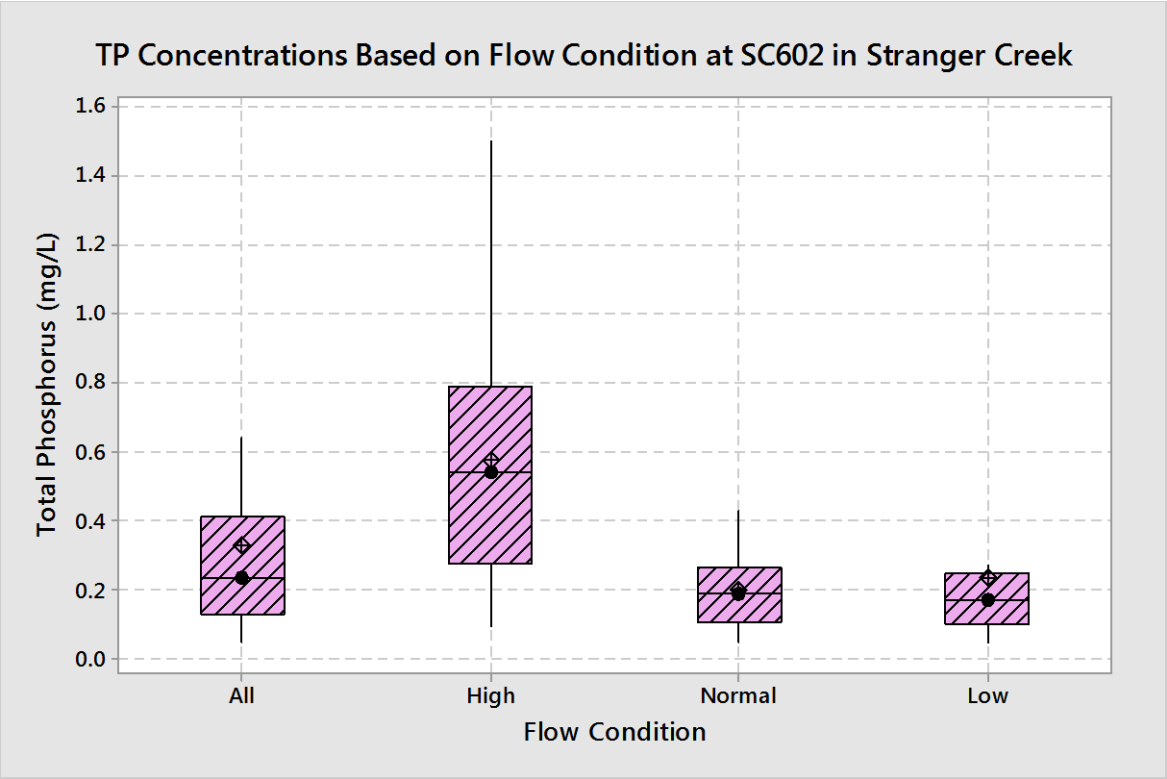

Figure 18. TP concentrations relative to flow condition at KDHE Sampling site SC602 in Stranger Creek.

Phosphorus concentrations when streams are at 0-25%, 26-75%, and 76-100% flow exceedance are represented in **Table 5**. TP concentrations for the corresponding flow exceedance percentiles were determined by averaging the samples collected while the stream was at 0-25%, 26-75%, and 76-100% flow exceedance.

Table 5. Total phosphorus concentrations at SC683in Crooked Creek and SC602 in Stranger Creek.

% Flow Exceedance		**Total Phosphorus Concentration by Range of Percent Flow Exceedance (mg/L)**		
		Average	Median	Maximum
SC683	0-25%	0.38	0.35	0.72
	26-75%	0.22	0.20	0.42
	76-100%	0.15	0.16	0.23
SC602	0-25%	0.57	0.54	1.50
	26-75%	0.20	0.19	0.43
	76-100%	0.24	0.17	1.02

Phosphorus is typically linked to sediment or total suspended solids (TSS) because of the propensity of those solids to adsorb phosphorus. As can be seen in **Figures 19 and 20**, TSS show a correlation to certain extent at SC683 and SC602 indicating that there is a good relationship when TSS > 100 mg/L. The spring season has the highest concentration of TSS at SC683 and SC602 due to spring runoff events.

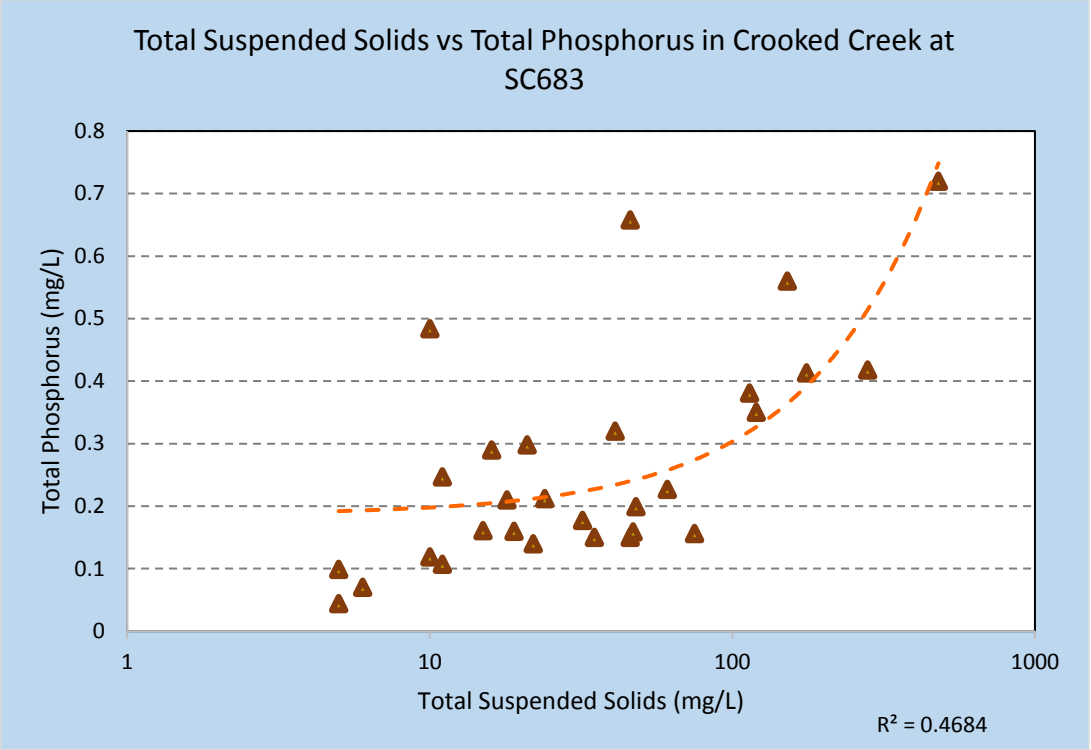

Figure 19. Relationship of total suspended solids to total phosphorus in the sampling site SC683 in Crooked Creek.

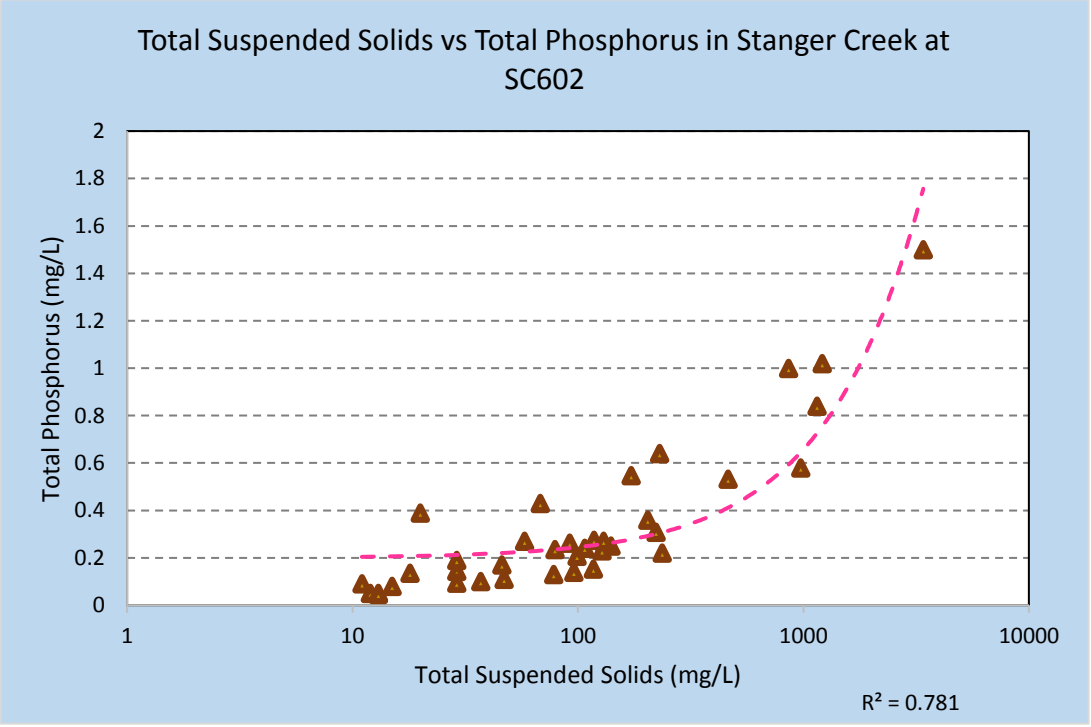

Figure 20. Relationship of total suspended solids to total phosphorus in the sampling site SC602 in Stranger Creek.

Levels of ortho-phosphate (o-P), the soluble portion of total phosphorus that is readily available for biological uptake, together with the sample's corresponding TP concentration can be seen in **Figures 21**

and 22. The ortho-phosphate reporting limit has increased over the period of record. In February of 2003 the reporting limit increased from 0.01 mg/L to 0.25 mg/L. Ortho-phosphate is present in the effluent of wastewater treatment plants and in the runoff from feedlots and grazing lands and may be detected downstream from the point of entry particularly during periods of low flow as can be seen in **Figure 23**.

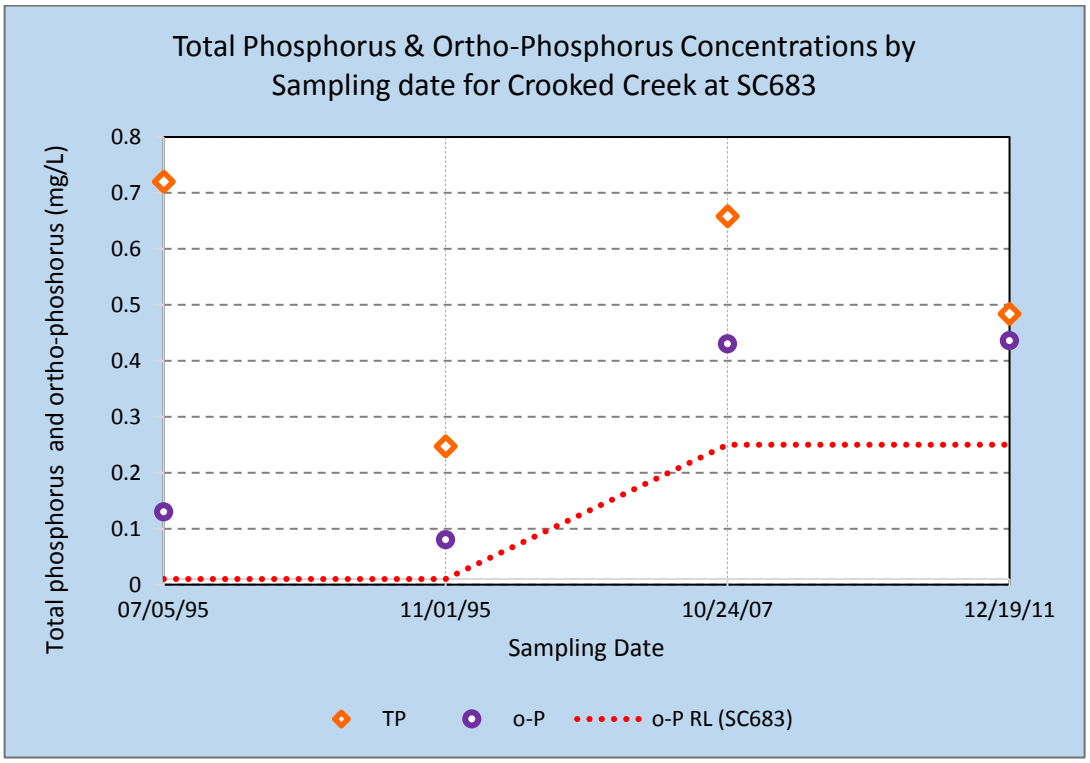

Figure 21. Ortho- phosphorus detections with corresponding total phosphorus values at SC683

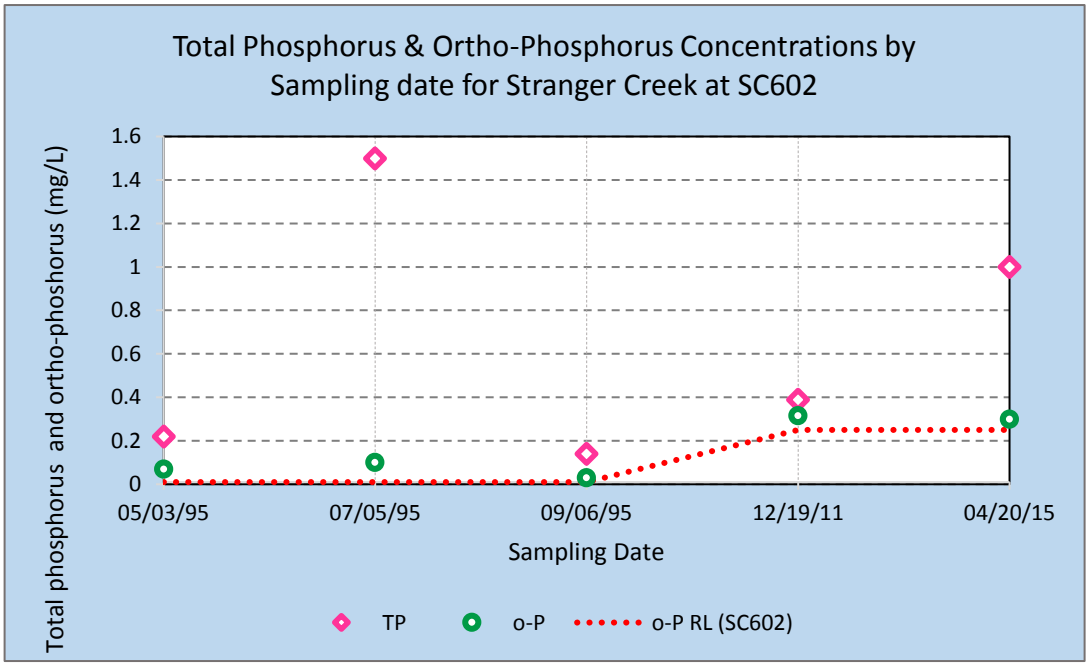

Figure 22. Ortho- phosphorus detections with corresponding total phosphorus values at SC602

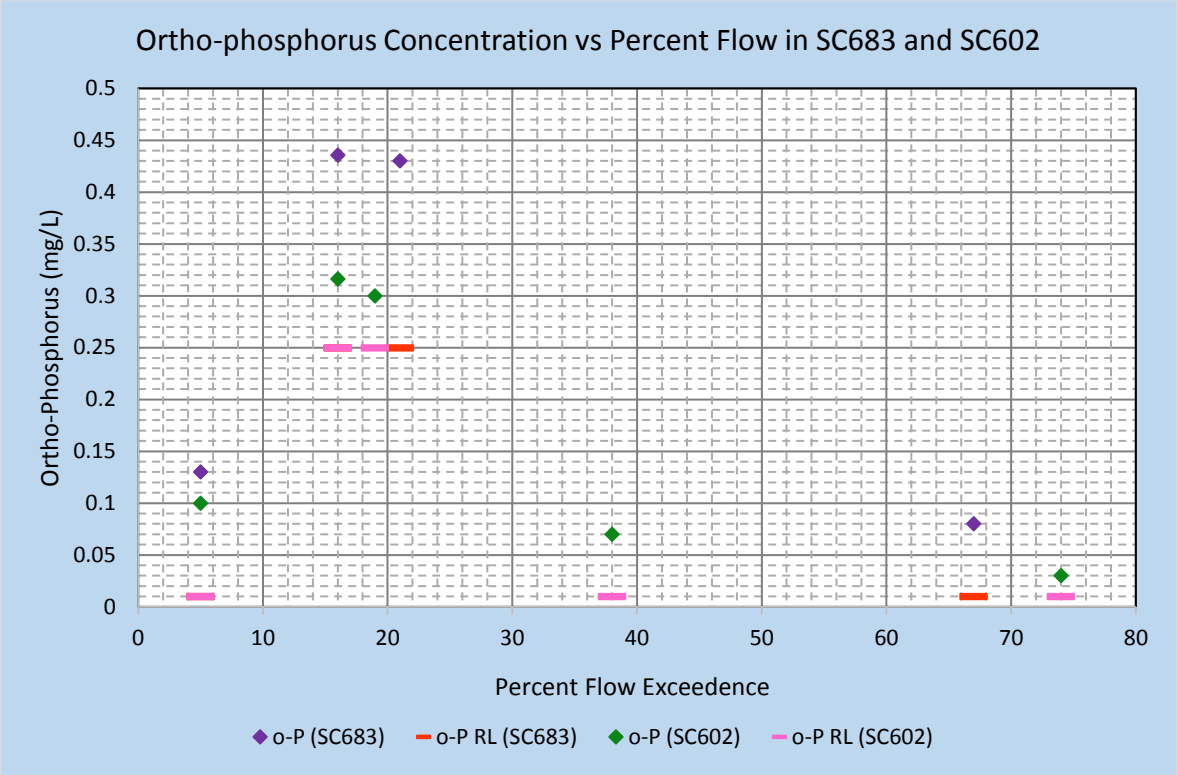

Figure 23. Ortho-phosphorus values greater than reporting limit versus percent flow exceedance in Crooked Creek (Sc683) and Stranger Creek (SC602).

Ortho-phosphate values that measured above the reporting limit (RL) at sampling sites SC683 and SC602 are used for the analysis and is presented in **Table 6**. Fourteen percent of the samples taken at SC683 and SC602 have measureable concentrations of o-P over the period of record. Twenty two and seventeen percent of samples taken during the summer-fall season in SC683 and SC602, respectively, measured above the reporting limit. No samples were above the reporting limit in spring season at SC683, whereas twenty percent of samples had measureable concentrations of o-P at SC602 in the spring.

Table 6. Average of the ortho-phosphorus values that measured above the reporting limit at sampling site SC683 and SC602

Sample information	Spring	Summer/Fall	Winter	All Seasons
SC683				
Average o-P (mg/L)	-	0.28	0.26	0.27
o-P > RL /Total # of Samples	-	2/9	2/10	4/29
% samples with o-P > RL	-	22%	20%	14%
SC602				
Average o-P (mg/L)	0.19	0.07	0.32	0.16
o-P > RL /Total # of Samples	2/10	2/12	1/15	5/37
% samples with o-P > RL	20%	17%	7%	14%

Relationship between Phosphorus and Biological Indicators: Dissolved Oxygen (DO) concentrations in Crooked Creek and Stranger Creek relative to the sampling date are represented in **Figures 24 and 25**. DO concentrations have fallen below the water quality standard (WQS) of 5.0 mg/L only once since 1995 at SC683. SC602 has always maintained DO concentrations greater than 5.0 mg/L since 1991. The DO violation occurred at SC683 in August when Crooked Creek was at low flow (76-100% flow exceedance) (**Figure 26**) and the stream temperature was 24 ^{o}C (**Figure 27**). **Figure 27** shows that, generally, as stream temperature increases, dissolved oxygen concentrations decrease.

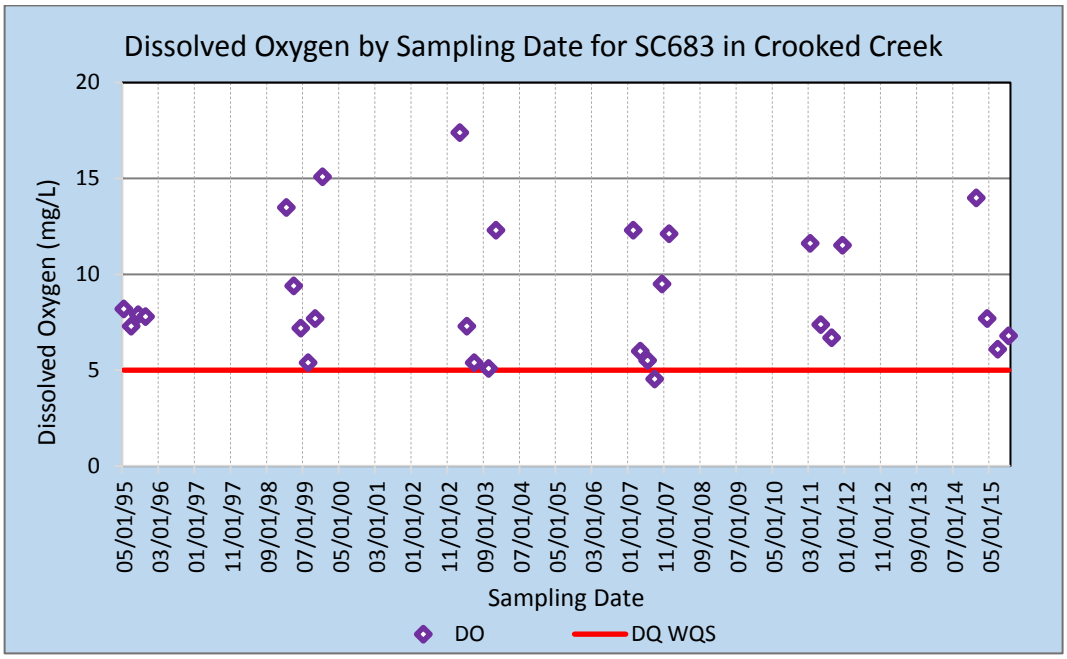

Figure 24. Dissolved oxygen concentration by sampling date at for KDHE Sampling Site SC683.

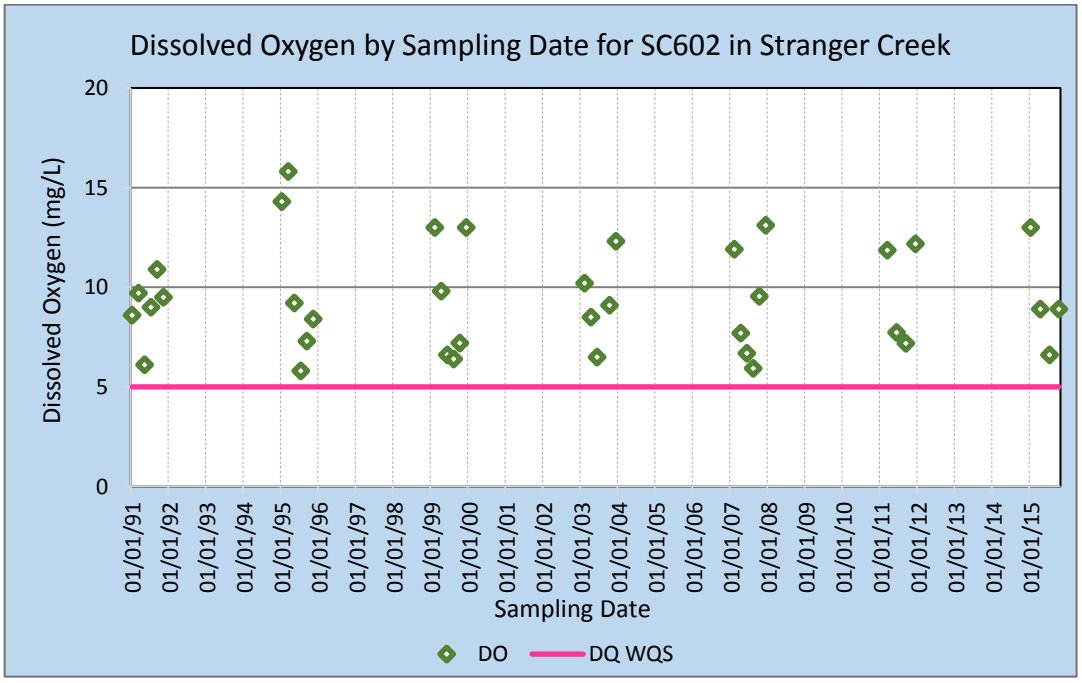

Figure 25. Dissolved oxygen concentration by sampling date at for KDHE Sampling Site SC602.

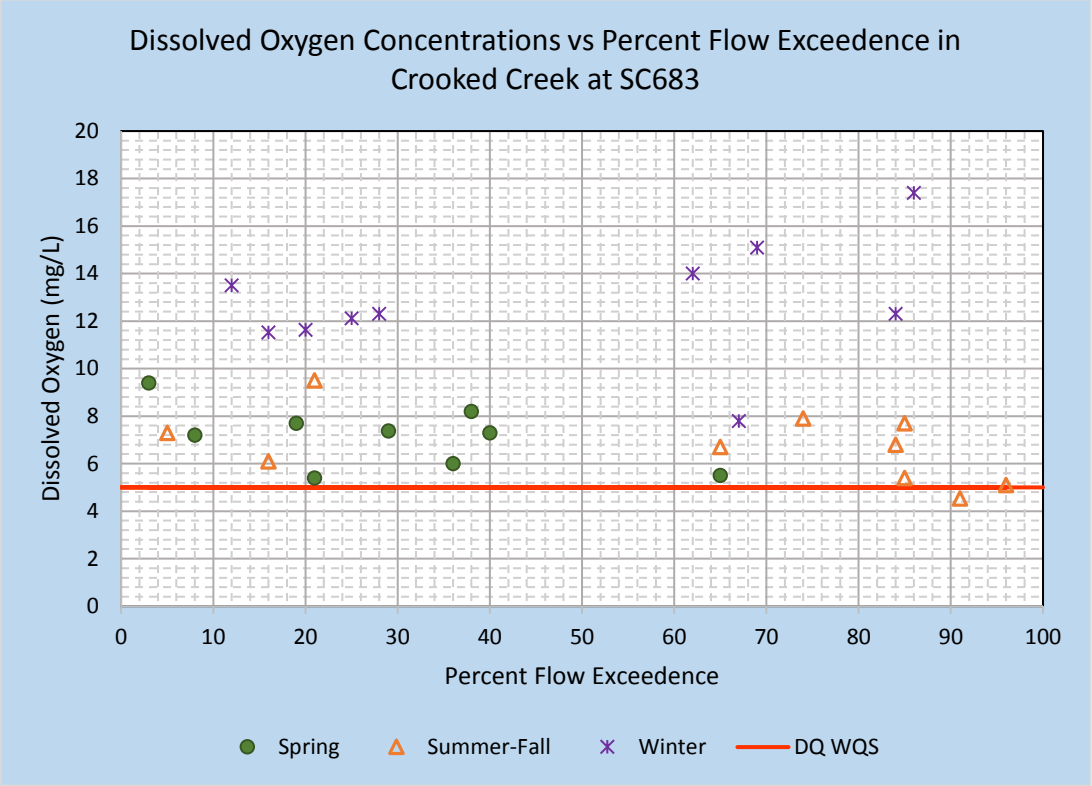

Figure 26. Seasonal dissolved oxygen concentrations by flow condition at SC683.

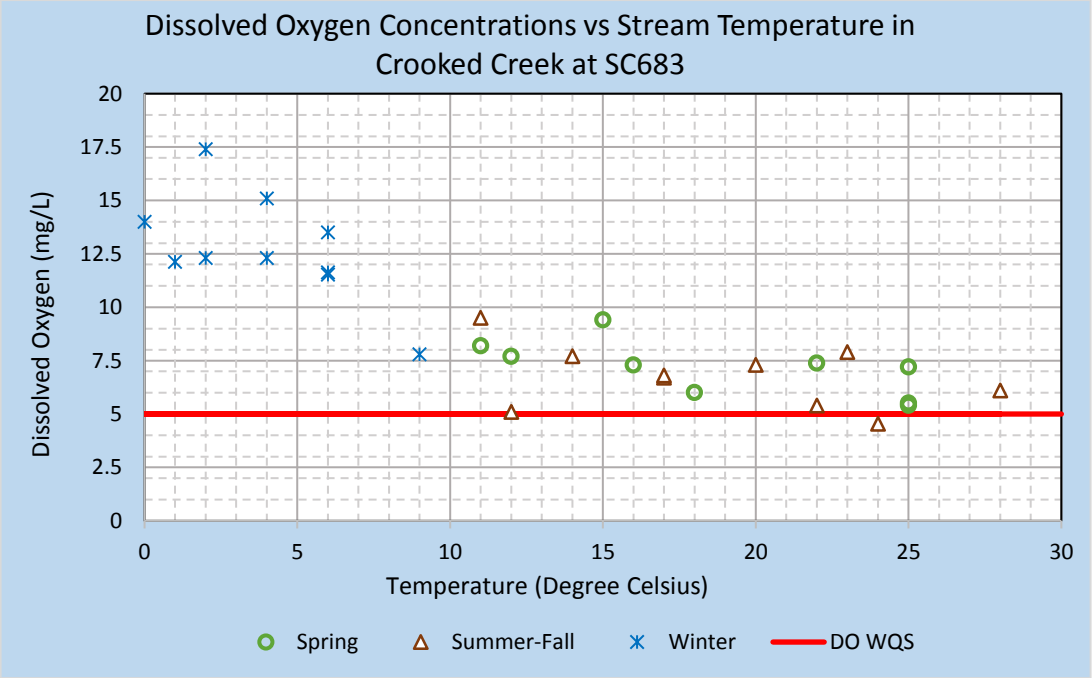

Figure 27. Stream temperature versus dissolved oxygen at SC683

The narrative criteria of the Kansas Surface Water Quality Standards are based on conditions of the prevailing biological community. Excessive primary productivity may be indicated by extreme swings in dissolved oxygen or pH as the chemical reaction of photosynthesis and respiration alter the ambient

levels of oxygen or acid-base balance of the stream. Dissolved oxygen is inversely related to the ambient temperature in the stream at SC683 and SC602 as displayed in **Figures 28 and 29**. It should be noted that samples collected prior to April 2003 were primarily collected in the afternoon hours, whereas samples collected later are in the morning hours.

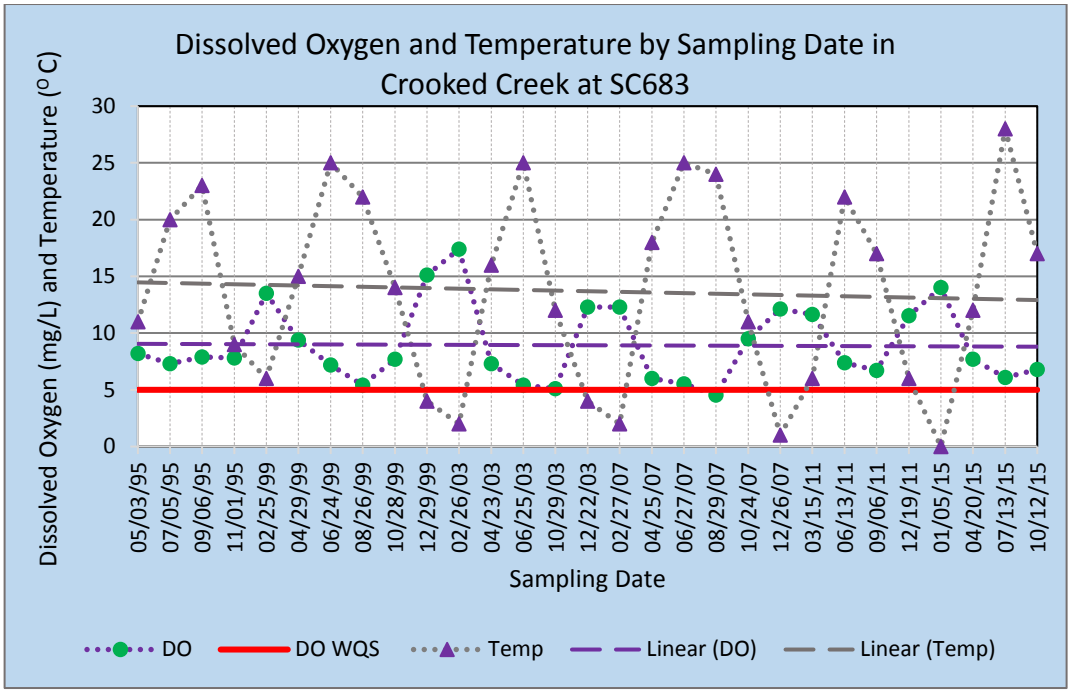

Figure 28. Dissolved Oxygen and Temperature by Sampling Date in Crooked Creek at SC683

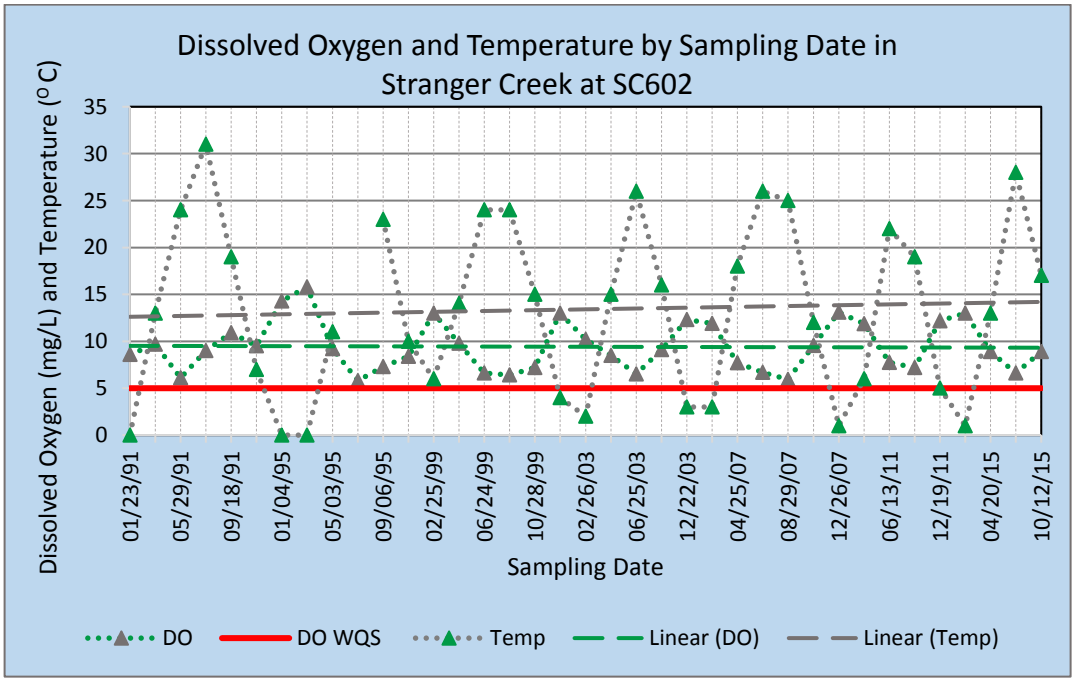

Figure 29. Dissolved Oxygen and Temperature by Sampling Date in Stranger Creek at SC602

To discount the impacts of temperature on the solubility of oxygen in the water column, the percent of saturated dissolved oxygen was computed from the data collected at the stations in Crooked Creek and

Stranger Creek. A seasonal pattern remained with a high percentage of dissolved oxygen saturation seen during cooler months while declines in percent saturation are associated with summer months. On average, pH values are consistent over the seasons while DO, temperature and oxygen saturation show an expected seasonal pattern with lowest average DO and oxygen saturation coinciding with the highest average temperature of the summer-fall season in SC683. At SC602 both the lowest DO and the lowest oxygen saturation are observed at 19.30 ^{o}C (**Table 7**). The relationship between temperature and percent oxygen saturation for SC683 and SC602 under low flow conditions are represented in **Figures 30 and 31**. The positive relationship at low flow at SC602 may indicate increased primary productivity.

Table 7. Average DO, temperature, % DO saturation, and pH samples at KDHE sampling site SC683 in Crooked Creek and SC602 in Stranger Creek.

Parameter	Spring	Summer-Fall	Winter	All Seasons
SC683				
Number of Samples	9.00	10.00	10.00	29.00
Dissolved Oxygen (mg/L)	7.12	6.71	12.77	8.93
Temperature (^{o}C)	18.78	18.80	4.00	13.69
Oxygen Saturation (%)	76%	71%	97%	81%
pH	7.62	7.64	7.61	7.62
SC602				
Number of Samples	10.00	12.00	15.00	37.00
Dissolved Oxygen (mg/L)	7.77	7.82	11.79	9.42
Temperature (^{o}C)	19.30	20.82	4.07	13.42
Oxygen Saturation (%)	83%	85%	89%	86%
pH	7.67	7.86	7.80	7.78

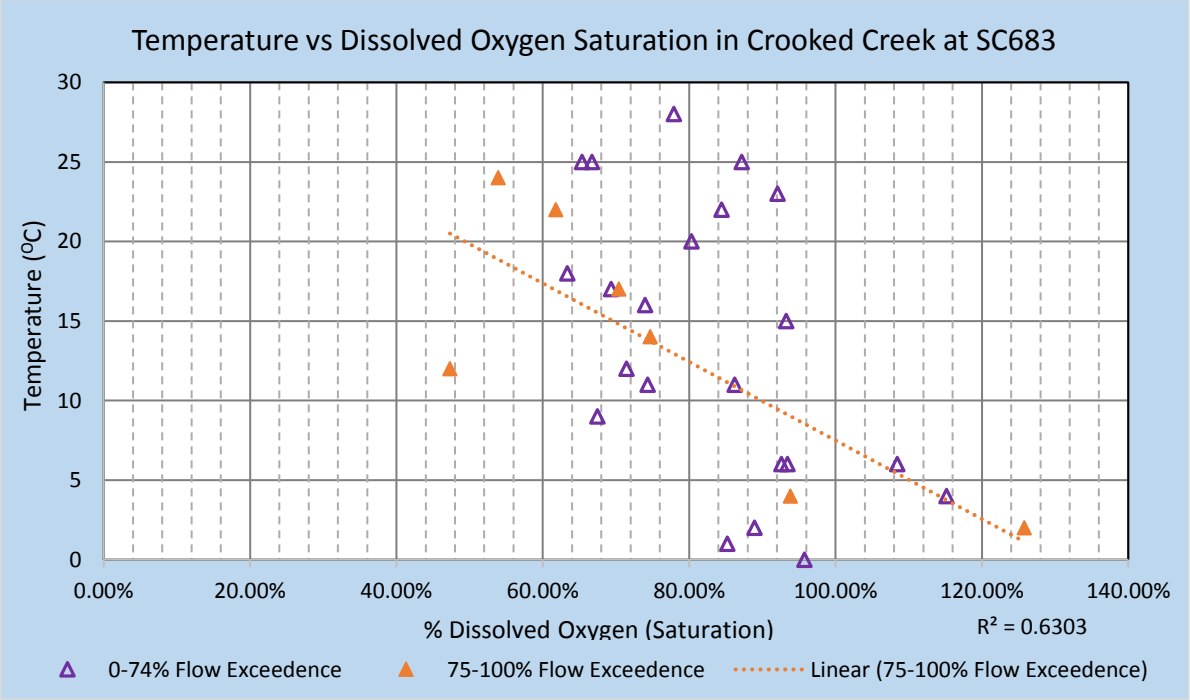

Figure 30. Relationship between temperature and percent Saturation of Dissolved Oxygen at SC683

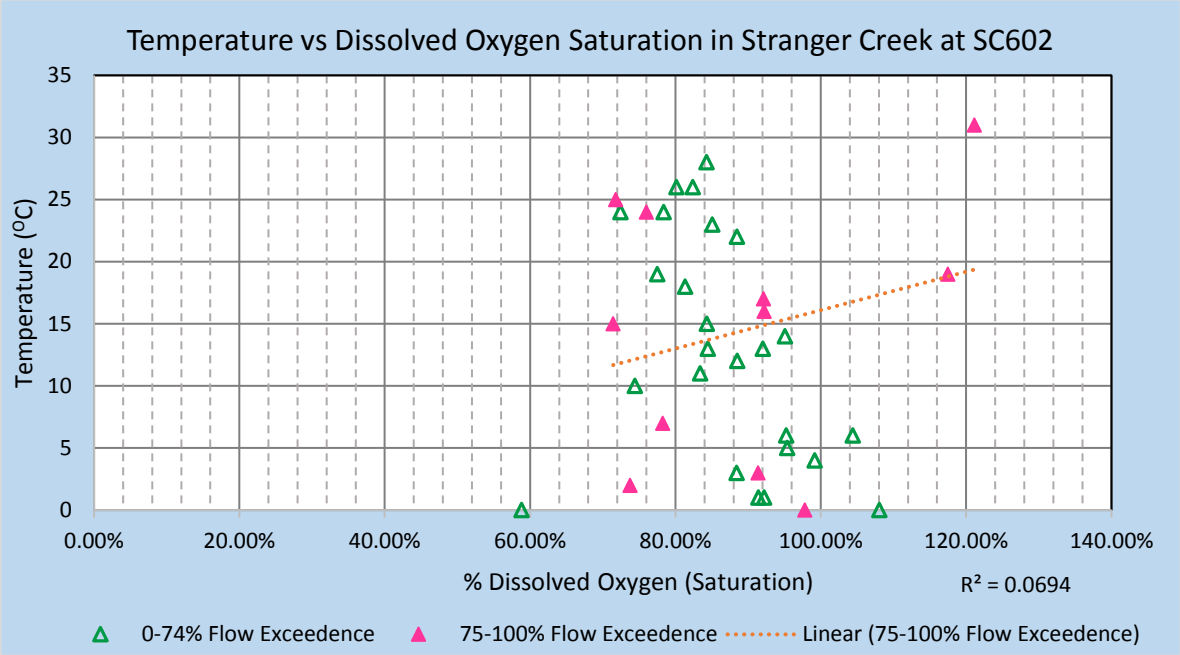

Figure 31. Relationship between temperature and percent Saturation of Dissolved Oxygen at SC602

The pH observed at SC683 and SC602 by sampling date is graphically represented in **Figures 32 and 33**. pH has never exceeded the criterion of 8.5 at both the sampling stations and over the years the pH has shown a decreasing trend. However, there is not a strong relationship between pH and dissolved oxygen at SC683 and SC602 for the period of record (**Figures 34 and 35**). Higher pH values tend to occur during periods when photosynthesis intensifies. **Figures 36 and 37** shows the relationship between pH and stream temperature at SC683 and SC602, respectively.

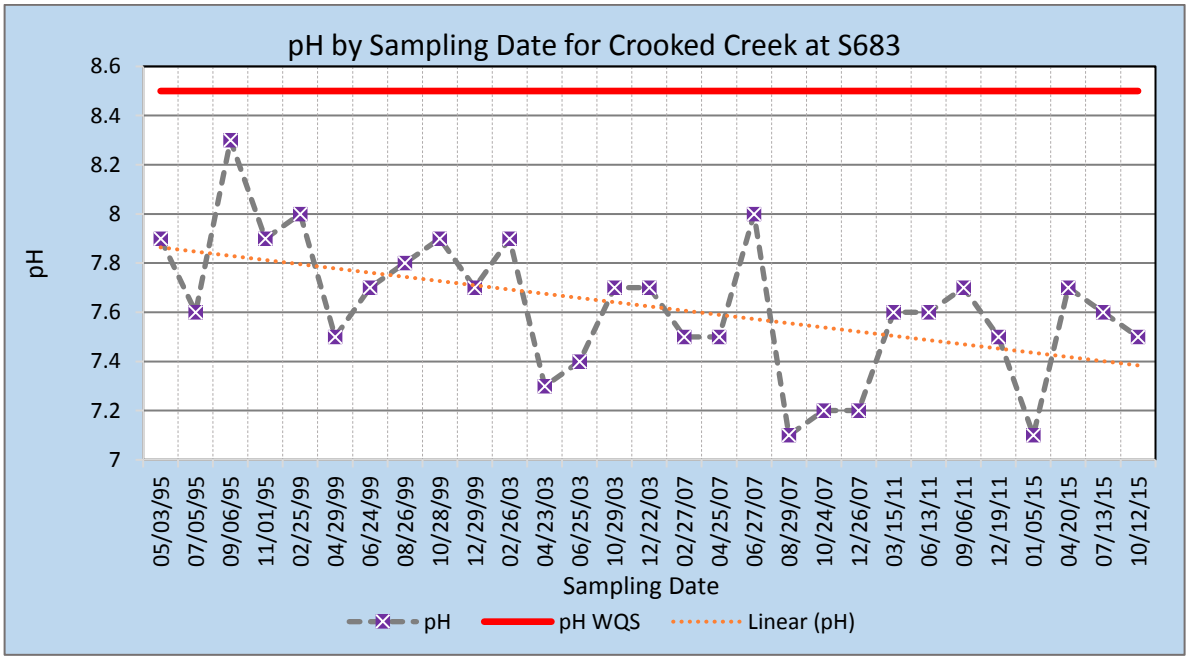

Figure 32. pH at KDHE Sampling Site SC683 by sampling date

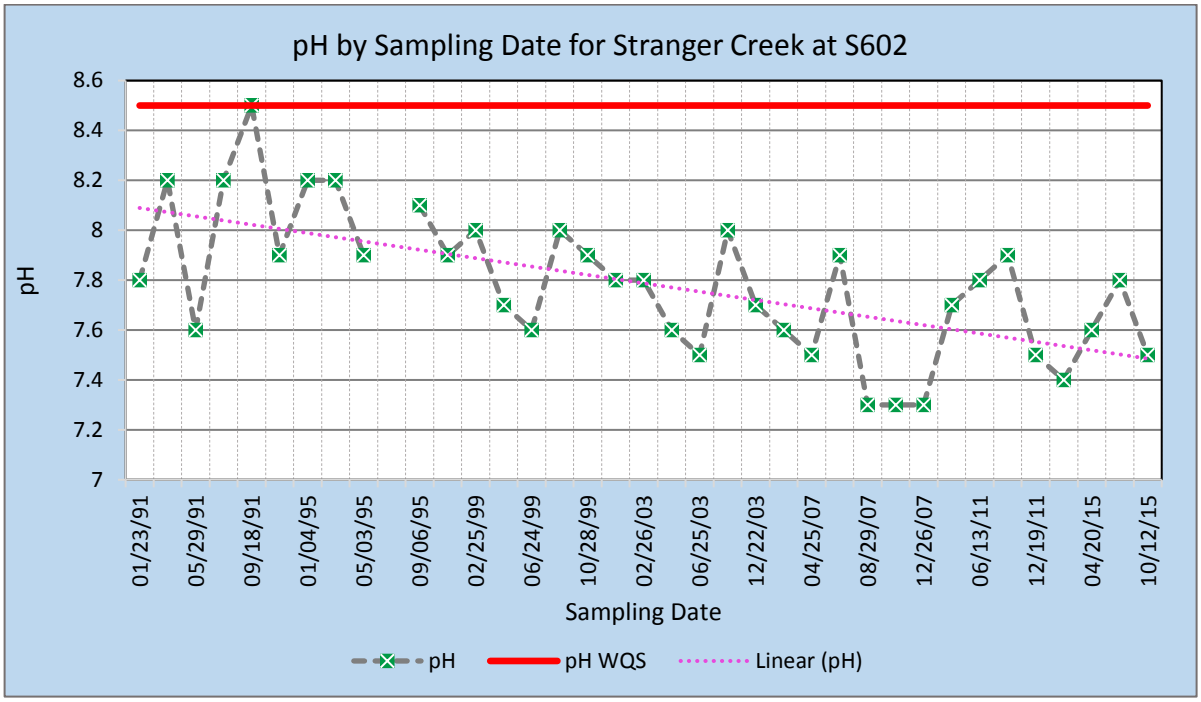

Figure 33. pH at KDHE Sampling Site SC602 by sampling date

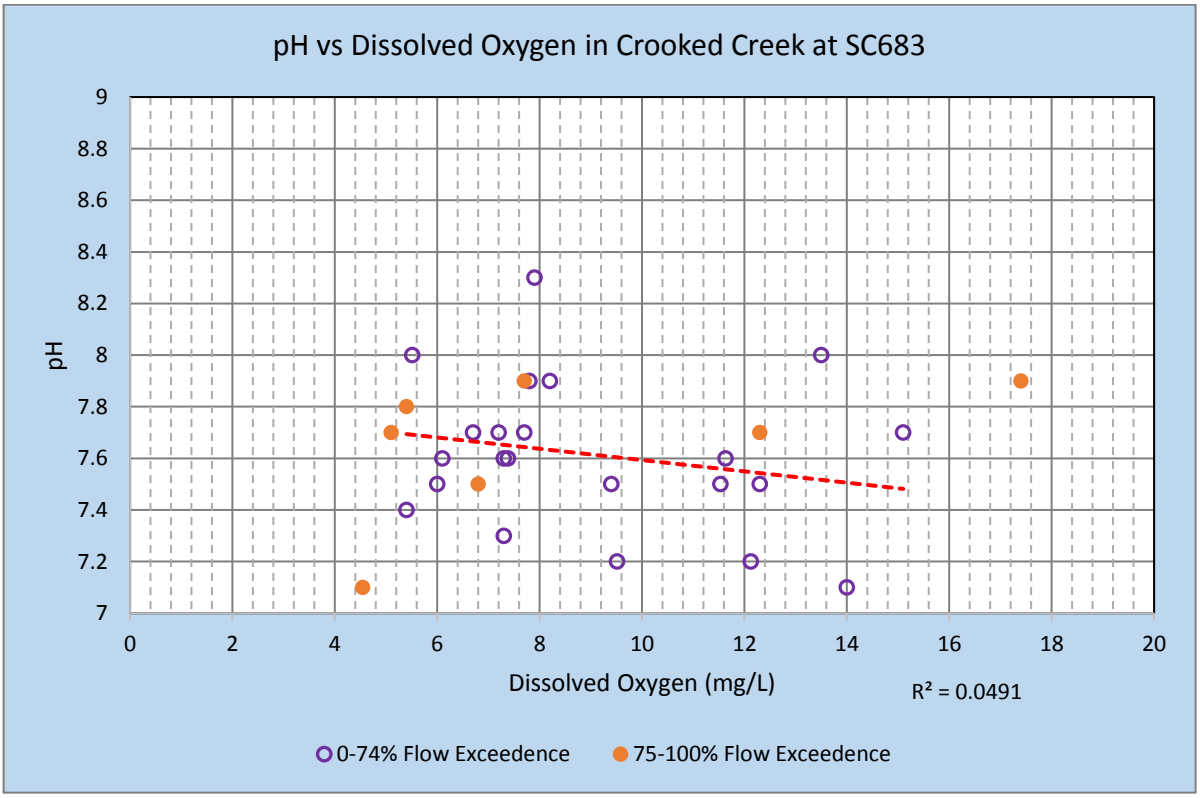

Figure 34. Relationship between pH and DO at SC683

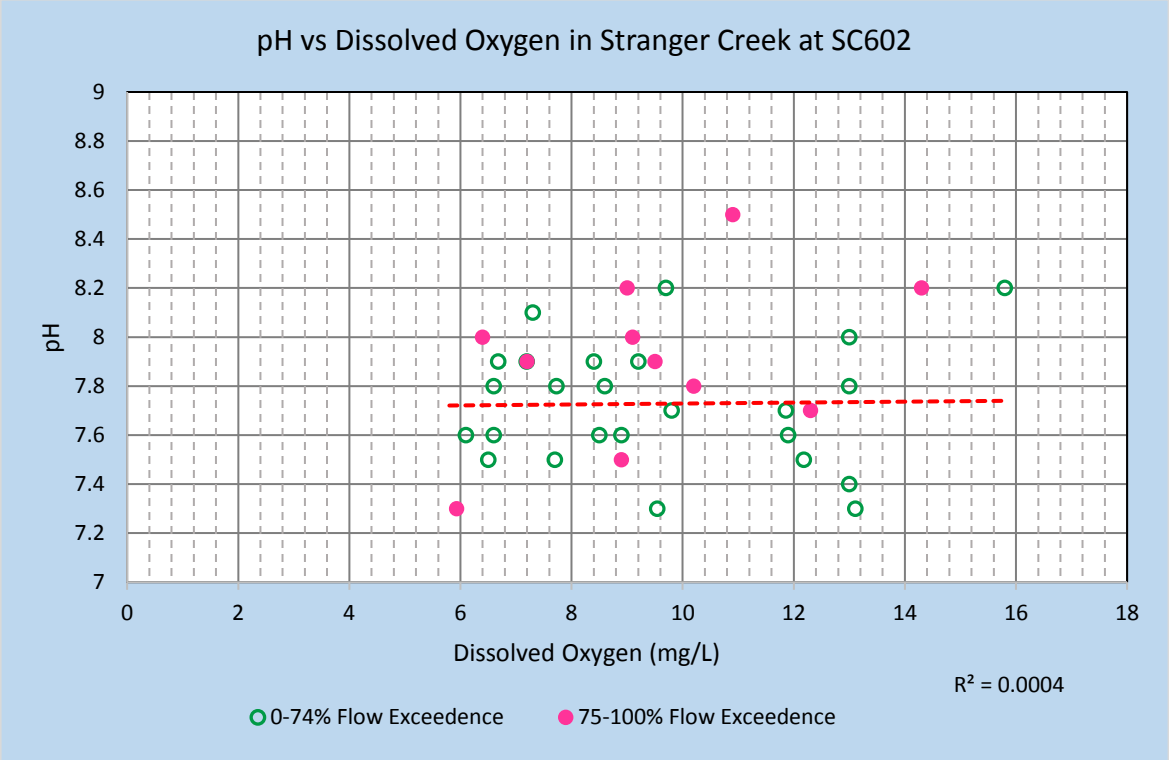

Figure 35. Relationship between pH and DO at SC602

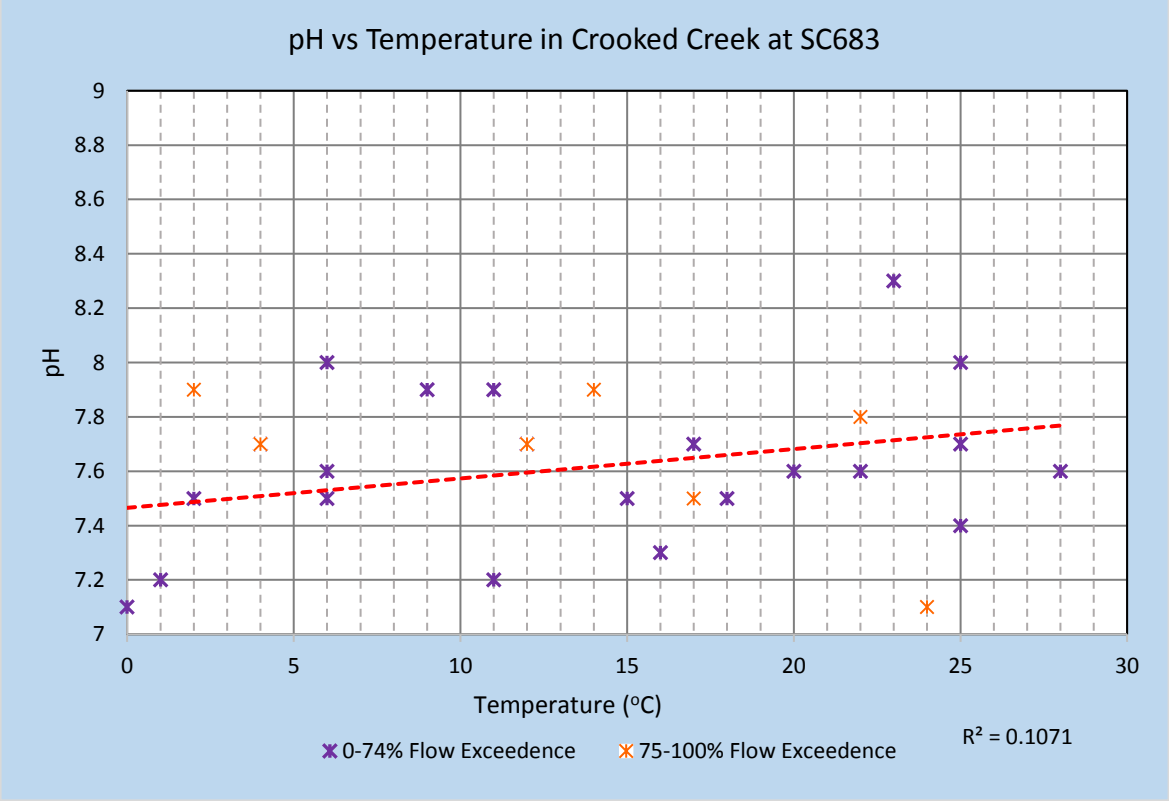

Figure 36. Relationship between pH and Temperature at SC683

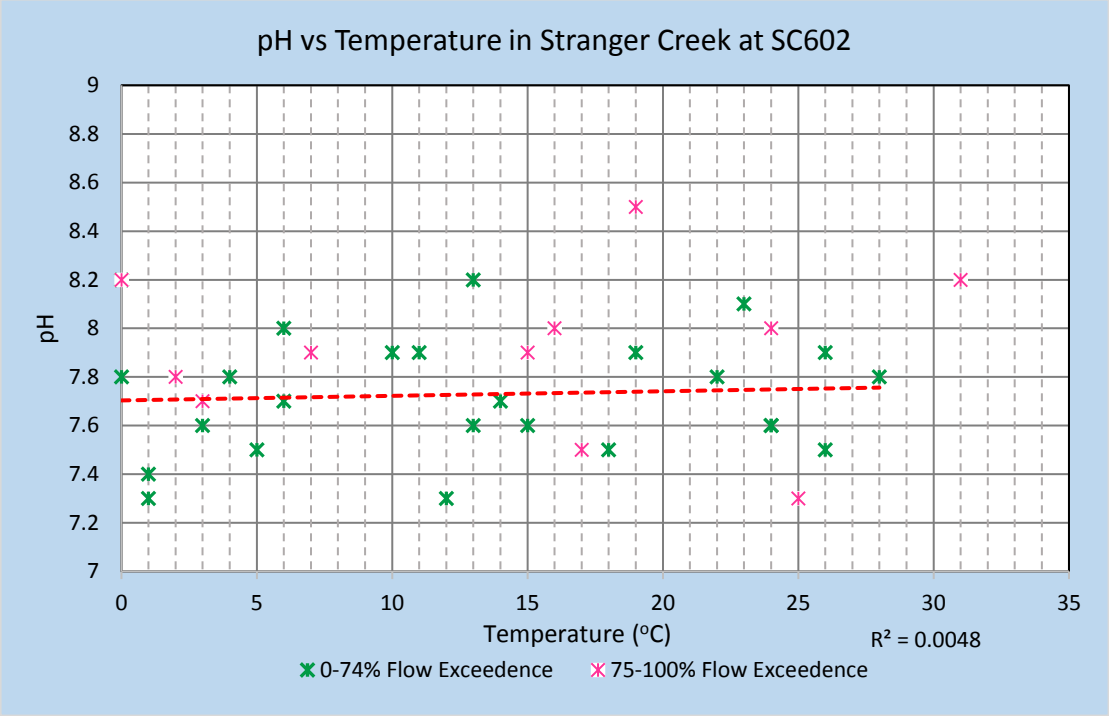

Figure 37. Relationship between pH and Temperature at SC602

Data available from KDHE's Stream Biological Monitoring Program for the Crooked Creek near Winchester was collected for a period of record from 1992-2014. To establish a historical perspective, the data was translated using the Aquatic Life Use Support Index (ALUS Index) as described in Kansas' 2016 303(d) Methodology. The ALUS Index consists of five categorizations of biotic condition that, once measured, are assigned a score (**Table 8**). Scores are then tallied and a support category is assigned according to **Table 9**.

1. Macroinvertebrate Biotic Index (MBI): A statistical measure that evaluates the effects of nutrients and oxygen demanding substances on macroinvertebrates based on the relative abundance of certain indicator taxa (orders and families).
2. Ephemeroptera, Plecoptera, and Trichoptera (EPT) abundance as a percentage of the total abundance of macroinvertebrates.
3. Kansas Biotic Index for Nutrients (KBI-N): Mathematically equivalent to the MBI, however, the tolerance values are species specific and restricted to aquatic insect orders.
4. EPT Percent of Count (EPT % CNT) – The percentage of organisms in a sample consisting of individuals belonging to the EPT orders.
5. Shannon's Evenness (SHN EVN) – A measure of diversity that describes how evenly distributed the numbers of individuals are among the taxa in a sample.

Table 8. ALUS Index metrics with scoring ranges.

MBI	KBI-N	EPT	EPT % CNT	SHN EVN	Score
<= 4.18	<= 2.52	>= 16	>= 65	>= 0.849	4
4.19-4.38	2.53-2.64	14-15	56-64	0.826-0.848	3
4.39-4.57	2.65-2.75	12-13	48-55	0.802-0.825	2
4.58-4.88	2.76-2.87	10-11	38-47	0.767-0.801	1
>= 4.89	>= 2.88	< = 9	<= 37	<= 0.766	0

Table 9. ALUS Index score range, interpretation of biotic condition, and supporting, partial, and no supporting categories.

ALUS Index Score	Biotic Condition	Support Category
17-20	Very Good	Supporting
14-16	Good	
7-13	Fair	Partially Supporting
4-6	Poor	Non-supporting
1-3	Very Poor	

The data available is limited to two sampling events per year in most of the years during 1992-2005. However, there is no data available for the year 1995 and 1996 has 5 samples. One sample per year was taken during years 2006-2014 with exceptions where no sampling done in 2008, 2010, 2011, and 2012. The site SB683 is located on Crooked Creek near Winchester. Biological data collected during 1992-2014 showed the biotic condition in Crooked Creek was fair to very poor resulting in partially-supporting and non-supporting ALUS Index for the stream (**Table 10**).

Table 10. Average ALUS scores at biology sampling sites in Crooked Creek (SB683) watershed.

Date of Sample	Number of Samples	Avg ALUS Index Score	Support Category
3/15/1992	1	3	Non- Supporting
7/4/1992	1	8	Partially- Supporting
5/31/1993	1	5	Non- Supporting
9/12/1993	1	9	Partially- Supporting
4/17/1994	2	2	Non- Supporting
7/15/1996	5	6.6	Partially- Supporting
5/14/1997	2	2.5	Non- Supporting
8/26/1998	2	9.5	Partially- Supporting
9/17/1999	2	12.5	Partially- Supporting
8/18/2000	2	12	Partially- Supporting
5/16/2001	2	2.5	Non- Supporting
7/5/2002	1	7	Partially- Supporting
5/13/2003	2	1	Non- Supporting
7/1/2004	2	4.5	Non- Supporting
10/13/2005	2	4.5	Non- Supporting
7/28/2006	1	4	Non- Supporting
9/14/2007	1	9	Partially- Supporting
7/11/2009	1	7	Partially- Supporting
5/16/2013	1	3	Non- Supporting
9/23/2014	1	4	Non- Supporting

Desired Endpoint: The ultimate endpoint of this TMDL will be to achieve the Kansas Surface Water Quality Standards by eliminating the objectionable flora and other impacts to aquatic life, domestic water supply, or recreation associated with excessive phosphorus as described in the narrative criteria pertaining to nutrients. There are no existing numeric phosphorus criteria currently in Kansas.

The average and median TP concentrations for each of the sampling stations within Ecoregion 40b and 47i were compared and summarized. **Table 11** details the percentiles of the TP concentrations for both the summary of the station averages and station medians. For station data in Ecoregion 40b and 47i, the 50th percentile of the station averages is 0.167 mg/L.

Table 11. Ecoregion 40b & 47i unimpaired station total phosphorus concentration summary by basin.

Ecoregion	Number of Stations	Average TP (mg/L)	50th Percentile of Averages (mg/L)	Average of Station Medians (mg/L)	50th Percentile of Station Medians (mg/L)	25th Percentile of Station Medians (mg/L)
40b & 47i	15	0.209	0.167	0.115	0.102	0.088

Stream biology sites located in Level IV Ecoregions 40b and 47i were identified and the average ALUS index was determined for those sites that had a stream biology data set greater than two samplings. Then, the median total phosphorus concentration was determined for those biology sites that had a corresponding total phosphorus data set at the stream biology site. The resulting plot (**Figure 38)** reveal conditions of full support span total phosphorus levels of 0.04 to 0.19 mg/L. This data set comprises 253 biology sampling events and 1,714 total phosphorus values at 23 SB/SC stations. **Figure 38** displays that once total phosphorus concentrations are greater than about 0.2 mg/L, conditions of full support are no longer observed.

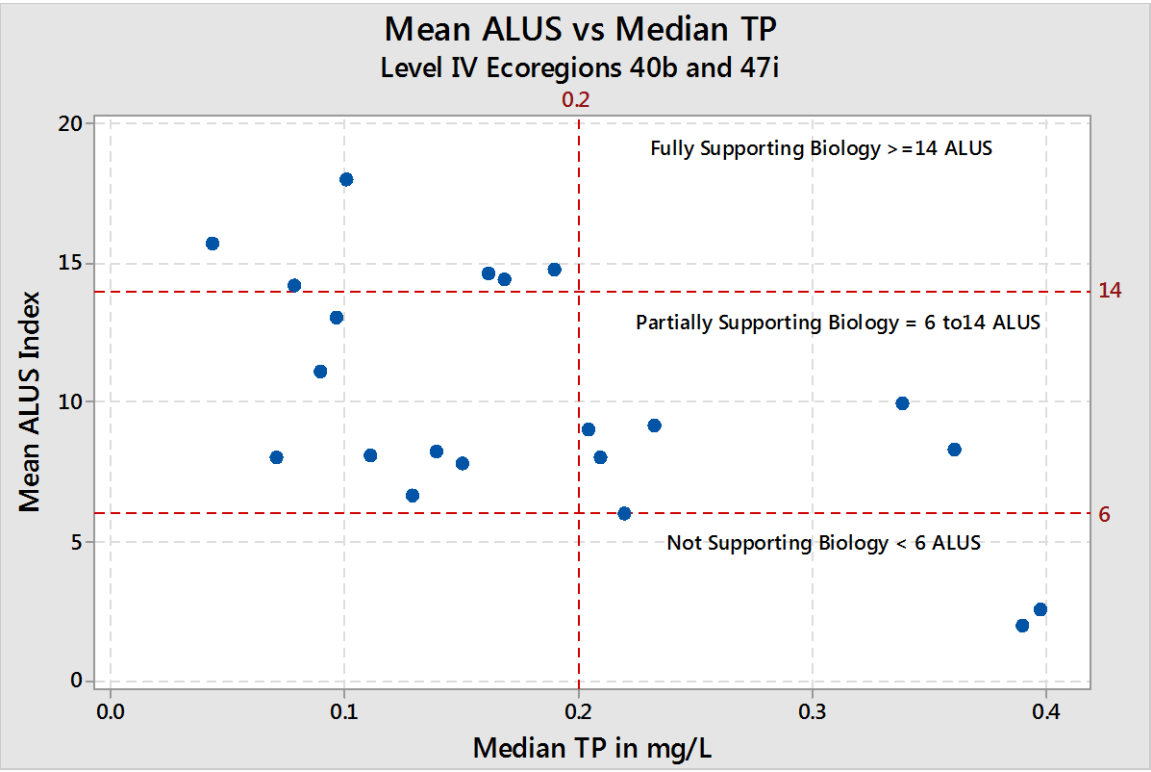

Figure 38. Mean aquatic life use score (ALUS) versus the median total phosphorus for stream chemistry/stream biology stations located in EPA Level IV Ecoregion 40b and 47i.

One of the complications in setting a total phosphorus milestone is establishing the linkage of phosphorus levels to applicable biologic response variables. Although **Figure 38** shows a somewhat noisy relationship with phosphorus in the partially supporting range, there is a clear delineation below 0.2

mg/L total phosphorus where streams move into the fully supporting category. For Crooked Creek and Stranger Creek, the total phosphorus milestone will be a median concentration of 0.167 mg/L, which is reflective of the 50th percentile of the averages of unimpaired stations located in Level IV Ecoregions 40b and 47i. The primary outcome will be improved ALUS Index scores resulting from reduced nutrient loading. The ALUS Index will serve to indicate if the biological community in Crooked Creek and Stranger Creek reflects recovery, renewed diversity, and minimal disruption by the impacts described in the narrative criteria for nutrients on aquatic life.

Additionally, the concentration of floating sestonic phytoplankton in the water column as determined by measuring the sestonic chlorophyll *a* concentrations in the creeks will indicate if primary productivity has moderated to reduce the impacts described in the narrative criteria for nutrients on aquatic life, recreation, and domestic water supply along the reaches of Crooked Creek and Stranger Creek.

Secondary indicators of the health of the in-stream biological community include:

1. Dissolved oxygen concentrations greater than 5.0 mg/L and the percent dissolved oxygen not more than 110%. Percent dissolved oxygen saturation is the measure of oxygen in the water relative to the water's potential dissolved oxygen concentration. Dissolved oxygen concentrations below 5.0 mg/L put aquatic life under stress while dissolved oxygen percent saturation levels greater than 110% are indicative of over-active primary productivity.
2. Instream pH values remain below 8.5. Excessive nutrients can induce vigorous photosynthesis which will cause pH to rise above 8.5, the current Kansas criterion.

Therefore, the numeric endpoints for this TMDL, as measured at SC/SB638 and SC602 indicating attainment of water quality standards within the watershed are:

1. An ALUS Index score greater than or equal to 14 at SB stations.
2. Maintain median sestonic chlorophyll *a* concentration equal to or below 10 µg/L at SC stations.
3. Dissolved oxygen concentrations greater than 5.0 mg/L at SC stations.
4. Dissolved oxygen saturation below 110% at SC stations.
5. pH values within the range of 6.5 to 8.5.

All five endpoints have to be initially maintained over three consecutive years at SC/SB638 and SC602 to constitute full support of the designated uses of Crooked Creek and Stranger Creek. After the endpoints are attained, simultaneous digression of these endpoints more than once every three years, on average, constitutes a resumption of impaired conditions in the streams unless the TP impairment is otherwise delisted through the 303(d) process.

These endpoints will be evaluated periodically as phosphorus levels decline in the watershed over time. This TMDL looks to establish a management milestone of a median TP concentration of 0.167 mg/L in Crooked Creek and Stranger Creek at SC638 and SC602, respectively, that would be the cue to examine for altered, improved biological conditions at SB638 and SC602.

Simultaneous achievement of the chlorophyll a, dissolved oxygen, oxygen saturation, and pH endpoints will signal phosphorus reductions are addressing the accelerated succession of aquatic biota and the development of objectionable concentrations of algae and algae by-products thereby restoring the domestic water supply and contact recreation uses in the river.

3.0 SOURCE INVENTORY AND ASSESSMENT

Point Sources: Stanger Creek watershed has two and seven NPDES permitted entities above sampling stations SC683 and SC602, respectively (**Table 12**). The two facilities above SC683 are discharging lagoons and represent the cities of Nortonville and Winchester. Similarly, three of the seven above sampling site SC602 are discharging lagoons representing the cities of Easton, Effingham and Lancaster. Hilltop Market is prohibited from discharging and are not assigned a total phosphorus wasteload allocation in Section 4. The Pennington, Easton and Mooney/Schrick quarries are permitted to discharge to the watershed but they are not required to monitor for phosphorus, since they are not expected to contribute to the phosphorus load at SC602. Hence, a wasteload allocation of zero been established for the three facilities. All of the discharging lagoons except the city of Winchester, were quarterly monitored for total phosphorus. Although the City of Winchester discharged 33 out of 36 quarters (2008-2016) they did not have any total phosphorous data as they were not required to monitor phosphorus in their discharge by their permit.

Table 12. NPDES permitted facilities and Current TP discharging data above the sampling station SC638 (Crooked Creek) and SC602 (Stranger Creek)

Kansas Permit No.	NPDES Permit No.	Facility Name	Design Flow (MGD)	Receiving Stream & Basin	Facility Type	Avg.TP (mg/l) in Effluent	Expiration Date
SC683							
M-KS50-OO01	KS0047562	Nortonville Wastewater Treatment Facility	0.0735	Stranger Cr. Via Crooked Cr.	Lagoon	3.52	11/30/2021
M-KS84-OO01	KS0047511	Winchester Wastewater Treatment Facility	0.103	Stranger Cr. Via Crooked Cr.	Lagoon	No Data	1/31/2022
SC602							
C-KS13-NO03	KSJ000623	Hilltop Market Wastewater Treatment Facility	NA	N/A	Lagoon Non-Discharging	NA	12/31/2017
I-KS13-PO02	KS0118486	Pennington Quarry # 66	NA	Stranger Cr.	Rock Quarry	NA	12/31/2016
I-KS13-PO04	KS0099538	Easton Quarry	NA	Stranger Creek Via Unnamed Tributary	Rock Quarry	NA	6/30/2017
I-KS50-PO01	KS0081604	Mooney/Schrick Quarry #83	NA	Stranger Cr. Via Crooked Cr. Via Mooney Cr.	Rock Quarry	NA	10/31/2021
M-KS13-OO01	KS0047261	Easton Municipal Wastewater Treatment Plant	0.0345	Stranger Cr.	Lagoon	1.51	9/30/2017
M-KS15-OO01	KS0047279	Effingham Wastewater Treatment Facility	0.107	Stranger Cr. Via Unnamed Tributary	Lagoon	2.17	12/31/2017
M-KS29-OO01	KS0024864	Lancaster Wastewater Treatment Facility	0.043	Kansas River Via N. Fork Stranger Cr.	Lagoon	2.24	12/31/2021

Land Use: The approximate land area of the SC683 and SC602 watershed is 189,509.69 acres. The land use percentages and acres within the watershed are in **Table 13** and are further illustrated in the land use map (**Figure 39**). Runoff from the cropland and developed areas could contribute significantly to total phosphorus loading. Land use within the Crooked Creek and Stranger Creek watershed is mostly pasture and grassland (47.83%) and cultivated crops (30.61%). The watershed has forested lands comprising 15.21% of the watershed, while developed land only account for about 5%.

Table 13. Land use data for Crooked Creek (SC683) and Stranger Creek watershed (SC602) (NLCD, 2011).

Land use	Area (acres)	Area (%)
Grassland/ Pasture	90,667.79	47.83
Cultivated Crops	58,021.61	30.61
Forest	28,823.88	15.21
Developed Land	9,453.10	4.99
Wetlands	1,375.29	0.73
Open Water	1,168.02	0.62
Barren Land	55.60	0.03

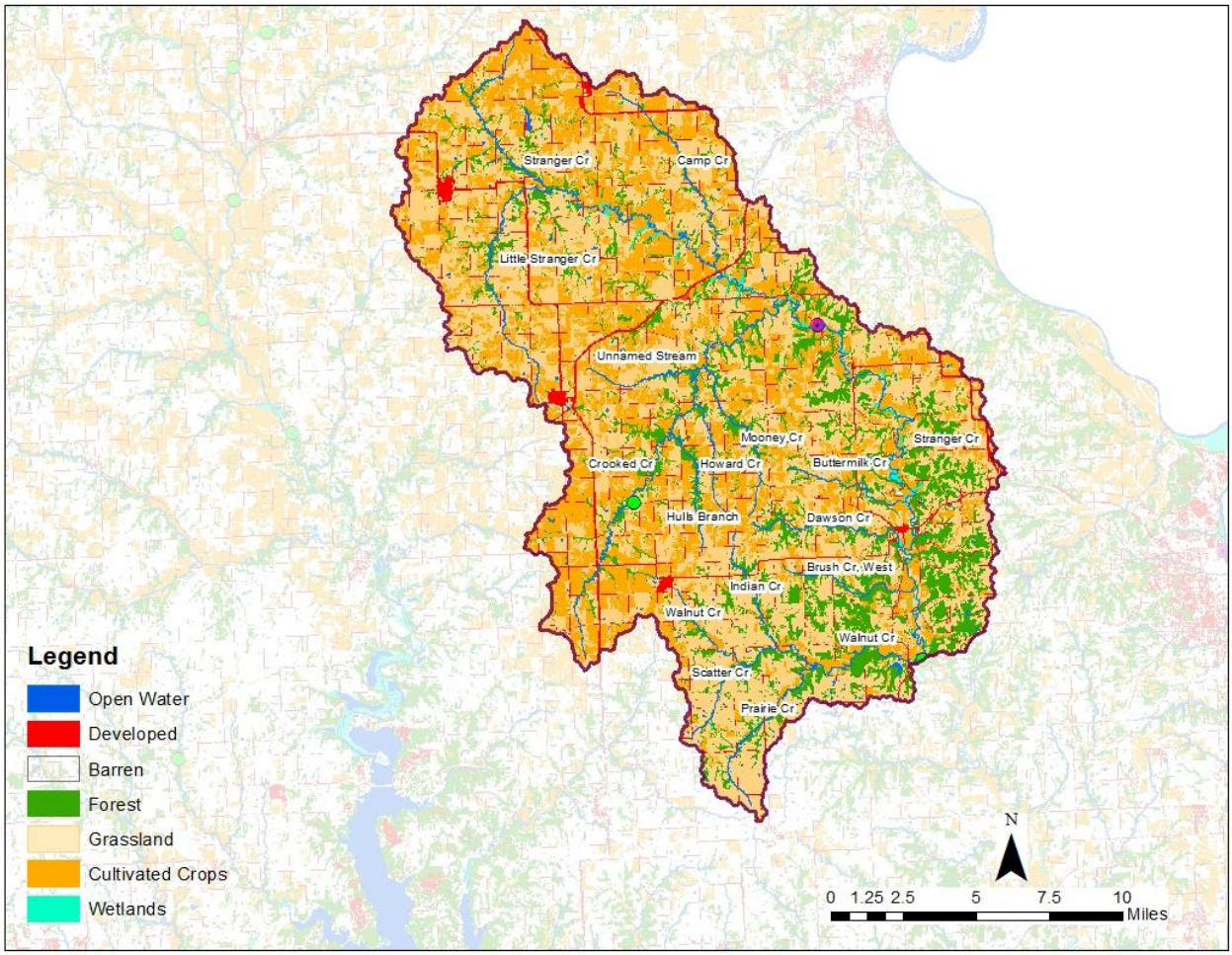

Figure 39. Land use map for Crooked Creek (SC683) and Stranger Creek watershed (SC602) (NLCD, 2011).

Livestock Waste Management Systems: The NPDES permitted animal feeding operation within the SC638 and SC602 watersheds are detailed in **Table 14**. There are seven facilities located in Atchison and Leavenworth counties and one located in Jefferson County. The permitted livestock facilities have waste management systems designed to minimize runoff entering their operation and detain runoff emanating from their facilities. These facilities are designed to retain a 25-year, 24-hour rainfall/runoff event as well as an anticipated two weeks of normal wastewater from their operations. Typically, this rainfall event coincides with streamflow that occurs less than 1-5% of the time. It is unlikely TP loading would be attributable to properly operating permitted livestock facilities, though extensive loading may occur if any of these facilities were in violation and discharged.

According to the USDA National Agricultural Statistics Service (NASS), on January 1, 2013 there was a decline in animal production between 2007 and 2012 (**Table 15**), although an increase in production was seen for poultry and sheep when compared to 2007. The animal waste from both confined and unconfined feeding sites is considered a potential source of total phosphorus loading in the streams in the watershed.

Table 14. Permitted and certified confined feeding operations Stranger Creek watershed.

KS Permit #	County	Animal Total	Permit Type	Animal Type
A-KSAT-MA12	Atchison	50	Certification	Dairy
A-KSAT-SA02	Atchison	572	Certification	Swine
A-KSAT-BA01	Atchison	150	Certification	Beef
A-KSLV-M008	Leavenworth	150	Permit	Dairy
A-MOLV-M001	Leavenworth	240	Permit	Dairy
A-KSLV-M005	Leavenworth	305	Renewal	Dairy
A-KSLV-M007	Leavenworth	256	Renewal	Dairy
A-KSJF-SA02	Jefferson	350	Certification	Swine

Table 15. County inventory of livestock, on January 1, 2013 and of hogs on December 1, 2012, USDA NASS.

County	**Year**	**Cattle and Calves**	**Poultry**	**Dairy**	**Horses**	**Sheep**	**Swine**
Atchison	2012	26,909	1,335	277	576	116	1,687
	2007	35,656	622	415	607	D	4,442
	Change in %	-25	115	-33	-5	NA	-62
Jefferson	2012	28,517	2,943	484	1,083	682	544
	2007	49,569	1,005	533	1,374	612	2,128
	Change in %	-42	193	-9	-21	11	-74
Leavenworth	2012	21,185	3,299	710	1,468	888	1,516
	2007	28,134	2,102	1,245	1,796	576	1919
	Change in %	-25	57	-43	-18	54	-21

D=Withheld to avoid disclosing data for individual farms.

On-Site Waste Systems: The Crooked Creek and Stranger Creek watersheds lies in an urban area where most residences are connected to public sewer systems. According to the Spreadsheet Tool for Estimating Pollutant Loads (STEPL), there are 2,089 septic systems in the SC683 and SC602 watershed. The

estimated septic failure rate in Kansas is somewhere in the 10-15% range, according to the survey performed by the Electric Power Research Institute. Failing on-site septic systems have the potential to contribute to nutrient loading in the watershed. However, because of the relatively small number of them, their small flows and because of phosphorus' proclivity for adsorbing to soil, failing on-site septic systems would be a minor source of phosphorus loading within the watershed and would not significantly contribute to the phosphorus impairment in Crooked Creek and Stranger Creek.

Population Density: The population in the watershed is detailed in **Table 16**. A change in population in the counties of the watershed is also listed. Atchison County shows a decline in population of 2.35 % whereas, Jefferson and Leavenworth shows an increase of 2.56% and 16.76%, respectively from 2010 Census to 2016 estimates. According to the 2010 census data from the U.S. Census Bureau, the population of the watershed is approximately 6,018 people, giving a population density of 20.43 people/square mile.

Table 16. U.S. 2000, 2010 Census results and a 2016 population estimate.

County/City	2000 Census	2010 Census	2016 Estimates	% Change from 2000 Census to 2016 Estimate
Atchison	16,774	16,924	16,380	-2.35%
Jefferson	18,426	19,126	18,897	2.56%
Leavenworth	68,691	76,227	80,204	16.76%

Source: United States Census Bureau

Contributing Runoff: The Crooked Creek and Stranger Creek watershed has mean soil permeability of 0.43 inches/hour, according to NRCS STATSGO database (**Figure 40**). Permeability in the watershed ranges from 0.01 to 17.6 inches/hour with about 50% of the watershed having extremely low permeability values of 0.57 inches/hour. Nearly 100% of the watershed has very low permeability values of 1.29 inches/hour or lower. According to a USGS open-file report (Juracek, 2000), the threshold soil-permeability values are set at 3.43 inches/hour for very high, 2.86 inches/hour for high, 2.29 inches/hour for moderate, 1.71 inches/hour for low, 1.14 inches/hour for very low, and 0.57 inches/hour for extremely low soil-permeability. Runoff is primarily generated as infiltration excess with rainfall intensities greater than soil permeability. As the watersheds' soil profiles become saturated, excess overland flow is produced. The majority of the nonpoint source nutrient runoff will be associated with cropland areas throughout the watershed that are in close proximity to the stream corridors.

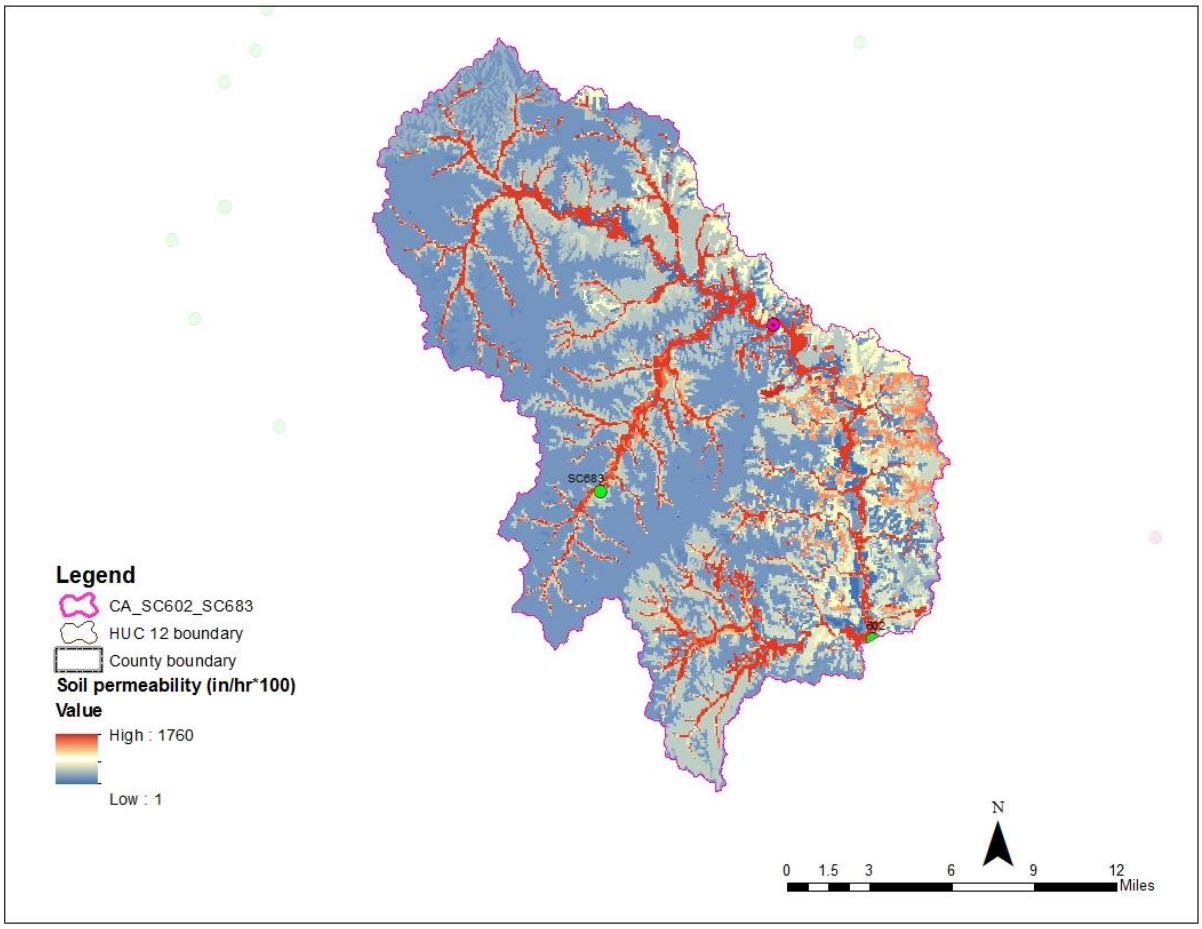

Figure 40. Soil permeability in Crooked Creek (SC683) and Stranger Creek (SC602) watersheds.

Background and Natural Sources: Phosphorus is present over the landscape, in the soil profile as well as terrestrial and aquatic biota. Wildlife can contribute phosphorus loadings, particularly if they congregate to a density that exceeds the assimilative capacity of the land or water.

4.0 ALLOCATION OF POLLUTION REDUCTION RESPONSIBLITY

The endpoint for this TMDL is based on the biological condition, pH, sestonic chlorophyll *a* and dissolved oxygen concentrations; all of which should improve to a level of full attainment of designated uses in Crooked Creek and Stranger Creek as median total phosphorus concentrations approach 0.167 mg/L. The application of riparian and livestock agricultural best management practices in the Crooked Creek and Stranger Creek watersheds should continue in order to abate and reduce total phosphorus loading from nonpoint sources. Once the concentrations in Crooked Creek and Stranger Creek approaches the target TP median concentration of 0.167 mg/L and sestonic chlorophyll *a* concentrations of less than 10 µg/L, an intensive assessment of macroinvertebrate abundance and diversity will be made to determine compliance with the narrative nutrient criteria.

Point Sources: The wasteload allocations (WLA) associated with the facilities located in the watershed are detailed in **Table 17**. The quarries have been assigned a wasteload allocation of zero as they are not expected to contribute to the phosphorus load in the streams. The non-overflowing lagoon system has been assigned a wasteload allocation of zero as well, as it is prohibited from discharging to the watershed.

The wasteload allocations associated with the municipal facilities are calculated based on their design flows and an effluent concentration of 2 mg/L TP, an effluent TP concentration commonly seen in Kansas lagoon systems. The total TP WLA for this TMDL is 2.95 lbs/day for Crooked Creek at terminus and 6.04 lbs/day (a total of 2.95 and 3.09 lbs/day) for Stranger Creek. TMDL allocations in Crooked Creek and Stranger Creek are graphically represented in **Figures 41 and 42**, respectively.

Table 17. Wasteload allocations for the NPDES permitted wastewater facilities above the sampling station SC638 (Crooked Creek) and SC602 (Stranger Creek)

Kansas Permit No.	NPDES Permit No.	Facility Name	Design Flow (MGD)	Anticipated TP Concentration (mg/L)	TP WLA Daily Load (lbs/day)	TP WLA Annual Load (lbs/year)
SC683						
M-KS50-OO01	KS0047562	Nortonville Wastewater Treatment Facility	0.0735	2	1.23	448.22
M-KS84-OO01	KS0047511	Winchester Wastewater Treatment Facility	0.103	2	1.72	628.12
Subtotal Industrial and Municipal Wasteload Allocation					**2.95**	**1,076.34**
SC602						
C-KS13-NO03	KSJ000623	Hilltop Market Wastewater Treatment Facility	NA	0	0	0
I-KS13-PO02	KS0118486	Pennington Quarry # 66	NA	0	0	0
I-KS13-PO04	KS0099538	Easton Quarry	NA	0	0	0
I-KS50-PO01	KS0081604	Mooney/Schrick Quarry #83	NA	0	0	0
M-KS13-OO01	KS0047261	Easton Municipal Wastewater Treatment Plant	0.0345	2	0.58	210.39
M-KS15-OO01	KS0047279	Effingham Wastewater Treatment Facility	0.107	2	1.79	652.52
M-KS29-OO01	KS0024864	Lancaster Wastewater Treatment Facility	0.043	2	0.72	262.23
Subtotal Industrial and Municipal Wasteload Allocation					**3.09**	**1,125.14**
Total Industrial and Municipal Wasteload Allocation					**6.04**	**2,201.48**

The established TMDL is depicted in **Figures 41 and 42** with current condition, load capacity (TMDL), wasteload allocation (WLA), load allocation (LA) in terms of pounds per day, under varying flow conditions, displayed in **Table 18**.

Nonpoint Source Load Allocation: The load allocation for nonpoint sources is the remaining load capacity after assimilated wasteloads for NPDES wastewater have been accounted for. Nonpoint sources are assumed minimal during low flow conditions. The load allocation grows proportionately as normal conditions occur.

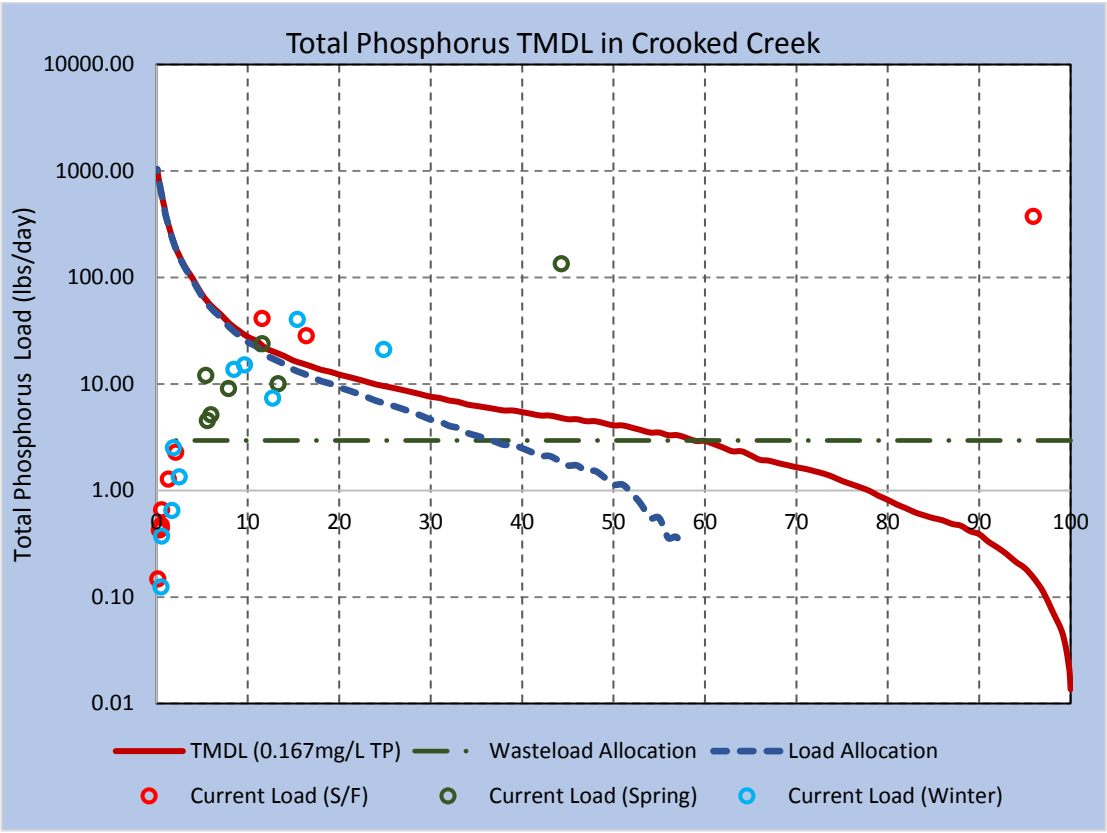

Figure 41. TMDL with wasteload allocations in Crooked Creek.

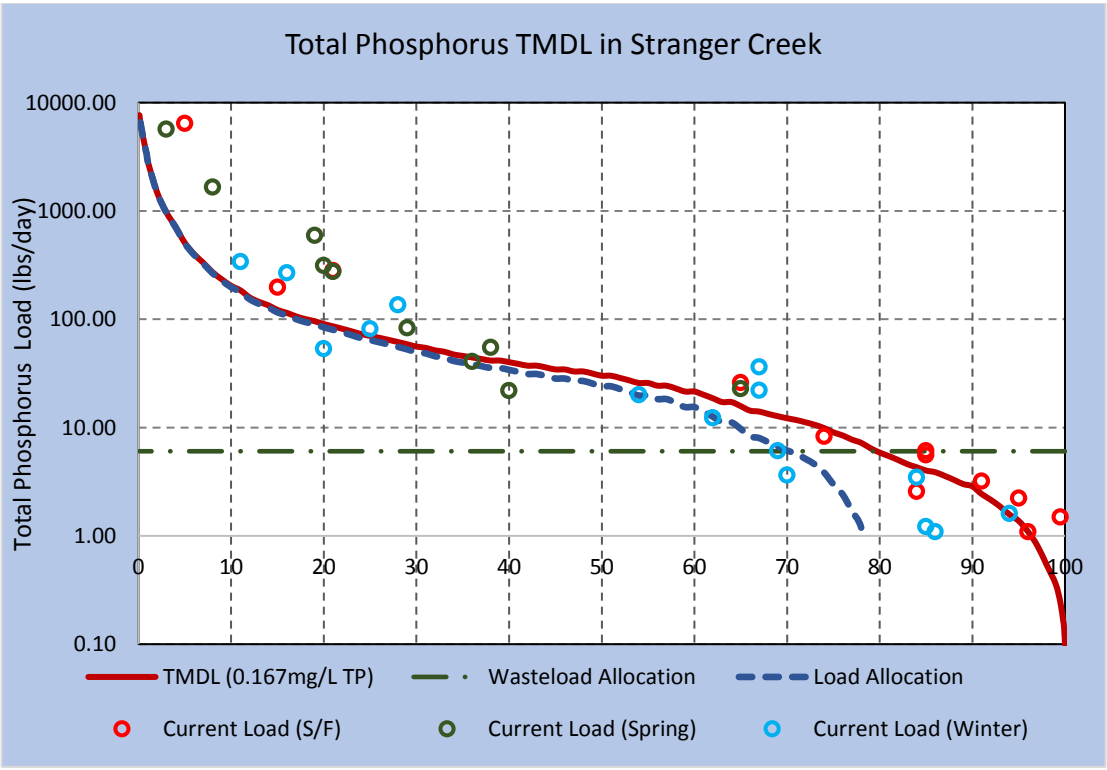

Figure 42. TMDL with wasteload allocations in Stranger Creek.

Table 18. Load capacities and allocations in Crooked Creek (SC683) and Stranger Creek (SC602)

Percent Flow Exceedance	Flow (cfs)	Current Condition (lbs/day)	Load Capacity (lbs/day)	Wasteload Allocation (lbs/day)	Load Allocation (lbs/day)
Crooked Creek					
90%	0.43	0.52	0.39	2.95	0
75%	1.36	1.66	1.23	2.95	0
50%	4.53	5.51	4.09	2.95	1.14
25%	10.57	12.85	9.53	2.95	6.58
10%	30.75	37.36	27.73	2.95	24.78
Stranger Creek					
90%	3.18	4.34	2.87	6.04	0
75%	10.01	13.67	9.03	6.04	2.99
50%	33.37	45.58	30.09	6.04	24.05
25%	77.87	106.35	70.22	6.04	64.18
10%	225.66	308.19	203.50	6.04	197.46

Defined Margin of Safety: The Margin of Safety provides some hedge against the uncertainty in phosphorus loading into Crooked Creek and Stranger Creek. This TMDL uses an implicit margin of safety, relying on conservative assumptions. Firstly, there are five endpoints that are established by this TMDL. Secondly, the sestonic chlorophyll *a* and biological endpoints used to assess compliance with the narrative criteria have to be maintained for three consecutive years before attainment of water quality standards can be claimed. Third, because there is often a synergistic effect of phosphorus and nitrogen on in-stream biological activity, concurrent efforts by municipal wastewater treatment facilities to reduce nitrogen content of its wastewater should complement the effect of phosphorus load reduction in improving the biological condition of Crooked Creek and Stranger Creek.

State Water Plan Implementation Priority: Early implementation of this TMDL will focus on riparian management in agricultural areas. Because these are tributaries to the Kansas River, a drinking water supply, this TMDL will be **High** Priority for implementation.

Nutrient Reduction Framework Priority Ranking: This watershed lies within the Lower Kansas Subbasin (HUC8: 10270104) with a priority ranking of 1 (Highest Priority for restoration work)/which is among the top sixteen HUC8s targeted for state action to reduce nutrients.

Priority HUC12s: Priority HUC12s within the watershed can be identified based on the cropland areas adjacent to the streams within the watershed. **Table 19** shows the HUC12s for the total phosphorus TMDL located in the SC683 and SC602 watersheds. This watershed is comprised of seven HUC 12s out of which four can be considered of high priority. HUC12s 102701040301, 102701040302, 102701040303, and 102701040304 have higher pounds of TP per acre and are located adjacent to the streams within the watershed.

Table 19. HUC 12 land use and estimated total phosphorus load based on land use at SC683 and SC602 (STEPL).

HUC 12	Urban Acres	Cropland Acres	Pasture and Grazing Land Acres	Forest Acres	Total Acres	TP Load (lbs/year)	TP lbs/year per Acre	SC Site
102701040301	334	13,451	19,867	3,221	36,872	29,624	0.80	SC602
102701040302	262	12,253	12,808	2,770	28,093	27,875	0.99	SC602
102701040303	332	10,557	8,785	1,924	21,598	23,824	1.10	SC683
102701040304	21	7,222	8,697	3,266	19,206	16,199	0.84	SC602
102701040305	78	6,049	9,895	4,421	20,443	13,848	0.68	SC602
102701040306	44	3,352	17,328	6,321	27,045	7,811	0.29	SC602
102701040307	153	4,648	12,405	7,462	24,668	10,828	0.44	SC602

5. IMPLEMENTATION

Desired Implementation Activities:

1. Make operational changes in municipal wastewater treatment lagoons and implement alternative disposal such as irrigation and, if necessary, install enhanced nutrient reduction technology to reduce wasteloads.
2. Renew state and federal permits and inspect permitted facilities for permit compliance.
3. Facilitate urban and construction stormwater management in Crooked Creek and Stranger Creek watershed including the city of Nortonville, Winchester, Easton, Effingham, and Lancaster, to abate pollutant loads using best management practices to the maximum extent practicable.
4. Implement and maintain conservation farming, including conservation tilling, contour farming, and no-till farming to reduce runoff and cropland erosion in agricultural areas of the watershed.
5. Improve riparian conditions along stream systems by installing grass and/or forest buffer strips along the stream and drainage channels in the watershed.
6. Perform extensive soil testing to ensure excess phosphorus is not applied.
7. Ensure land applied manure is being properly managed and is not susceptible to runoff by implementing nutrient management plans.
8. Install pasture management practices, including proper stock density to reduce soil erosion and storm runoff.
9. Ensure that labeled application rates of chemical fertilizers are being followed and implement runoff control measures.
10. The stakeholder leadership team for the Upper Kansas watershed WRAPS will coordinate BMPs to address:
    a. Livestock: vegetative filter strips, relocate feeding sites, relocate pasture feeding sites off-stream and alternate watering system.
    b. Cropland: waterways, terraces, conservation crop rotations and water retention structures.

NPDES and State Permits – KDHE

a. Monitor influent into and effluent from the discharging permitted wastewater treatment facilities, continue to encourage wastewater reuse and irrigation disposal and ensure compliance and proper operation to control phosphorus levels in wastewater discharges.

b. Establish applicable permit limits and conditions after 2021, with the initial implementation of goals and appropriate schedules of compliance for permits issued prior.
c. Inspect permitted livestock facilities to ensure compliance.
d. New livestock permitted facilities will be inspected for integrity of applied pollution prevention technologies.
e. New registered livestock facilities with less than 300 animal units will apply pollution prevention technologies.
f. Manure management plans will be implemented, to include proper land application rates and practices that will prevent runoff of applied manure.
g. Reduce runoff in MS4 permitted areas through stormwater management programs.
h. Establish nutrient reduction practices among urban homeowners to manage application on lawns and gardens, through respective stormwater management programs.

Nonpoint Source Pollution Technical Assistance – KDHE

a. Support Section 319 implementation projects for reduction of phosphorus runoff from agricultural activities as well as nutrient management.
b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips.
c. Provide technical assistance on nutrient management for livestock facilities in the watershed and practices geared towards small livestock operations, which minimize impacts to stream resources.
d. Support the implementation efforts of the Middle Kansas WRAPS and incorporate long-term objectives of this TMDL into their 9-element watershed plan.
e. Engage the municipalities in the watershed to discuss stormwater load trading opportunities.

Water Resource Cost Share and Nonpoint Source Pollution Control Program – KDA-DOC

a. Apply conservation farming practices and/or erosion control structures, including no-till, terraces, and contours, sediment control basins, and constructed wetlands.
b. Provide sediment control practices to minimize erosion and sediment transport from cropland and grassland in the watershed.
c. Install livestock waste management systems for manure storage.
d. Implement manure management plans.

Riparian Protection Program – KDA-DOC

a. Establish or reestablish natural riparian systems, including vegetative filter strips and streambank vegetation.
b. Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.
c. Promote wetland construction to reduce runoff and assimilate sediment loadings.
d. Coordinate riparian management within the watershed and develop riparian restoration projects.

Buffer Initiative Program – KDA-DOC

a. Install grass buffer strips near streams.
b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.

Extension Outreach and Technical Assistance – Kansas State University

a. Educate agricultural producers on sediment, nutrient, and pasture management.
b. Educate livestock producers on livestock waste management, land applied manure applications, and nutrient management planning.
c. Provide technical assistance on livestock waste management systems and nutrient management planning.
d. Provide technical assistance on buffer strip design and minimizing cropland runoff.
e. Encourage annual soil testing to determine capacity of field to hold phosphorus.
f. Educate residents, landowners, and watershed stakeholders about nonpoint source pollution.
g. Promote and utilize the WRAPS efforts for pollution prevention, runoff control and resource management. The WRAPS coordinator is also an extension watershed specialist that will provide technical assistance and outreach to producers for BMP implementation. Other entities for this task include NRCS and local conservation districts.

Timeframe for Implementation: Reduction strategies for the mechanical wastewater treatment facility should be evaluated by 2019 with subsequent planning, design, and construction of any necessary enhanced treatment initiated by the next permit starting in 2022. Urban stormwater and rural runoff management should expand in 2017 to ensure nutrients are addressed. Pollutant reduction practices should be installed within the priority subwatersheds before 2022 with follow-up implementation over 2022-2027.

Targeted Participants: The primary participants for implementation will be municipal wastewater and stormwater programs, and agricultural and livestock producers operating immediately adjacent to the Crooked Creek and Stranger Creek and its tributaries. Watershed coordinators and technical staff of the WRAPS, along with Conservation District personnel and county extension agents should assess possible sources adjacent to streams. Implementation activities to address nonpoint sources should focus on those areas with the greatest potential to impact nutrient concentrations adjacent to the river.

Targeted Activities to focus attention toward include:

1. High-density urban and residential development in proximity to streams and tributary areas.
2. Urban residents should be informed on fertilizer and waste management through their respective municipal Stormwater Management Programs to reduce urban runoff loads.
3. Overused grazing land adjacent to the streams.
4. Sites where drainage runs through or adjacent to livestock areas.
5. Sites where livestock have full access to the stream as a primary water supply.
6. Poor riparian area and denuded riparian vegetation along the stream.
7. Unbufferred cropland adjacent to the stream.
8. Conservation compliance on highly erodible areas.
9. Total row crop acreage and gully locations.

Milestone for 2023: By 2023, advancement of necessary and appropriate measures to decrease the effluent phosphorus content from the municipal wastewater facilitiy should be implemented. At that point in time, phosphorus data from the Crooked Creek and Stranger Creek stream chemistry station SC683 and SC602 should show indication of declining concentrations relative to the pre-2016 data, particularly during low and normal flow conditions.

Delivery Agents: The primary delivery agents for program participation will be municipalities within the watershed, KDHE, and the conservation projects within and above the TMDL watershed.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution:

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.

2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

3. K.S.A. 2002 Supp. 82a-2001 identifies the classes of recreation use and defines impairment for streams.

4. K.A.R. 28-16-69 through 71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

5. K.S.A. 2-1915 empowers the Kansas Department of Agriculture, Division of Conservation to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

6. K.S.A. 75-5657 empowers the Kansas Department of Agriculture, Division of Conservation to provide financial assistance for local project work plans developed to control nonpoint source pollution.

7. K.S.A. 82a-901, et. seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

8. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the Kansas Water Plan, including selected Watershed Restoration and Protection Strategies.

9. The Kansas Water Plan and the Kansas Regional Planning Area plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority implementation.

Funding: The State Water Plan annually generates $12-13 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the Kansas Water Plan. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watershed and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are located within a **High** Priority area and should receive support for pollution abatement practices that lower the loading of sediment and nutrients.

Effectiveness: Use of Biological Nutrient Removal technology has been well established to reduce nutrient levels in wastewater, including phosphorus. Additionally, nutrient control has been proven effective through conservation tillage, contour farming and use of grass waterways and buffer strips. In addition, the proper implementation of comprehensive livestock waste management plans has proven

effective at reducing nutrient runoff associated with livestock facilities. Presuming the biological endpoints are not met, this TMDL will be reevaluated after 2028 to assess the reductions in phosphorus loads and concentrations and the desired endpoints.

6. MONITORING

Stream chemistry sampling will include sestonic chlorophyll a sampling at SC683 and SC602 once stream TP concentrations approach 0.2 mg/L. Monitoring of TP should be a condition of the MS4 permits within the TMDL watershed.

Once TP concentrations approach 0.2 mg/L in Crooked Creek and Stranger Creek, macroinvertebrate sampling at SB683 will be performed to assess the biotic integrity of the stream. If the biological endpoints are achieved over 2023-2027 at SB683, the conditions descried by the narrative nutrient criteria will be viewed as attained and Crooked Creek and Stranger Creek will be moved to Category 2 on the 2028-303(d) list.

Once the water quality standards are attained, the adjusted ambient phosphorus concentrations in Crooked Creek and Stranger Creek will be the basis for establishing numeric phosphorus criteria through the triennial water quality standards process to protect the restored biological and chemical integrity of the stream.

7. FEEDBACK

Public Notice: An active Internet Web site is established at http://www.kdheks.gov/tmdl/planning_mgmt.htm to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Kansas-Lower Republican River Basin. This TMDL was posted to this site on June 8, 2017 for public review.

Public Hearing: A Public Hearing on Crooked Creek and Stranger Creek TP TMDL was held in Topeka, Kansas on June 28, 2017 to receive comments on this TMDL.

Milestone Evaluation: In 2023, evaluation will be made as to the degree of implementation that occurred within the TMDL watershed. Subsequent decisions will be made through the WRAPS regarding the non-points source implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: Crooked Creek and Stranger Creek will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2017-2027. Therefore, the decision for delisting will come about in the preparation of the 2028 303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL, and implementation activities may be adjusted accordingly.
Incorporation into the TMDL Vision Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Kansas TMDL Vision Process, the next anticipated revision would come in 2022, which will emphasize implementation of WRAPS activities and reduction of nutrients in wastewater developed by NPDES facilities. At that time, incorporation of this TMDL will be made into the WRAPS watershed plans. Recommendations of this TMDL will be

considered in the Kansas Water Plan implementation decisions under the State Water Planning Process for Fiscal Years 2017-2025.

Developed 06/07/17

References

Electric Power Research Institute Survey on Septic System Failure Rate found at: http://it.tetratech-ffx.com/steplweb/Faq.htm#Q4

Juracek, K.E., 2000. Soils – Potential Runoff. U.S. Geological Survey Open-File Report 00-253.

Kansas Department of Health and Environment. 2010. Kansas Reference Streams: Selection of Suitable Candidates, Impending threats To Reference Stature, And Recommendations For Long-Term Conservation.

Kansas Department of Health and Environment. 2016. Methodology for the Evaluation and Development of the 2016 Section 303(d) List of Impaired Water Bodies for Kansas. http://www.kdheks.gov/tmdl/download/2014_303_d_Methodology.pdf

Kansas Surface Water Quality Standards and Supporting Material found at: http://www.kdheks.gov/water/download/kwqs_plus_supporting.pdf

National Oceanic and Atmospheric Administration, National Centers for Environmental Information. Accessed 10/6/2016: Custom Global Summary, Precipitation (PRCP), Station GHCND: USC00142652. http://www.ncdc.noaa.gov/cdo-web/confirmation

National Land Cover Database, 2011. http://www.mrlc.gov/

Perry, C.A., D.M. Wolock and J.C. Artman. 2004. Estimates of Flow Duration, Mean Flow, and Peak-Discharge Frequency Values for Kansas Stream Locations, USGS Scientific Investigations Report 2004-5033.

STEPL Support and Septic System Failure Rate found at: http://it.tetratech-ffx.com/steplweb/Faq.htm#Q4

United States Army Corps of Engineers. 2013. Annual Report of Reservoir Regulation Activities. http://www.nwk.usace.army.mil/Portals/29/13AnnualRep.pdf

United States Army Corps of Engineers. 2014. Monthly Charts of Reservoir Data. http://www.swt-wc.usace.army.mil/ELDRcharts.html

United States Census Bureau. 2010. http://www.census.gov/

United States Department of Agriculture. State of Kansas Quick Stats. https://www.nass.usda.gov/Statistics_by_State/Kansas/index.php